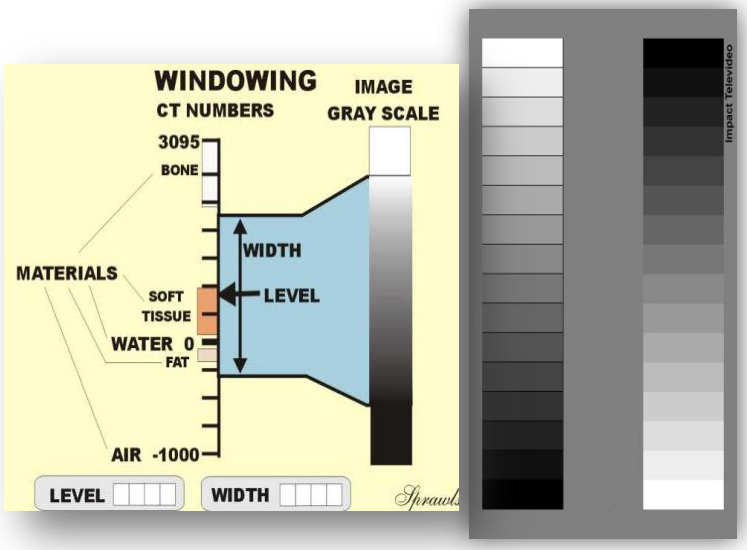
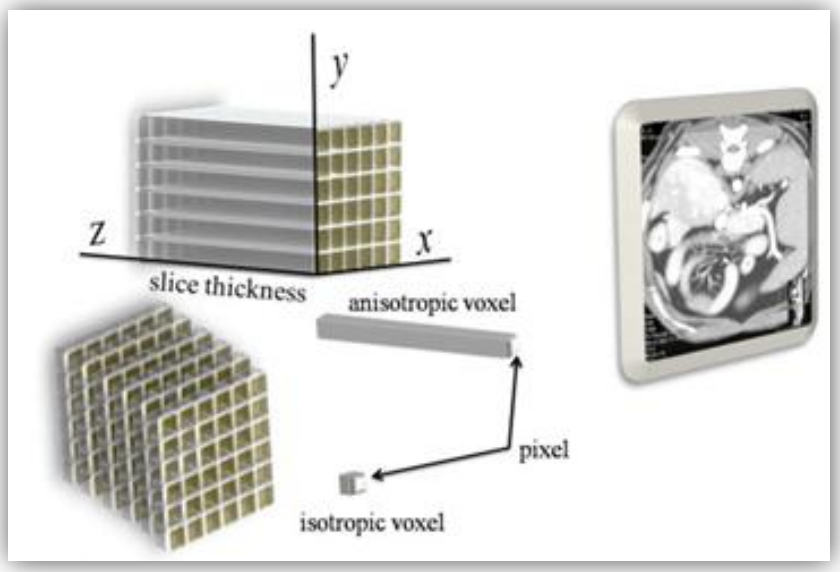
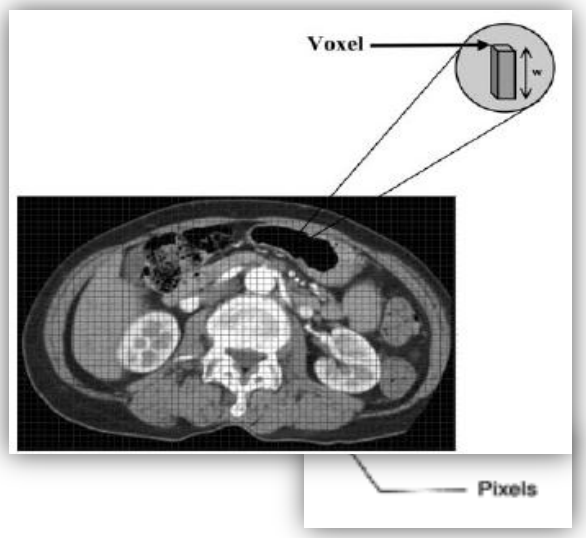
X ray sectional imaging (CT imaging)

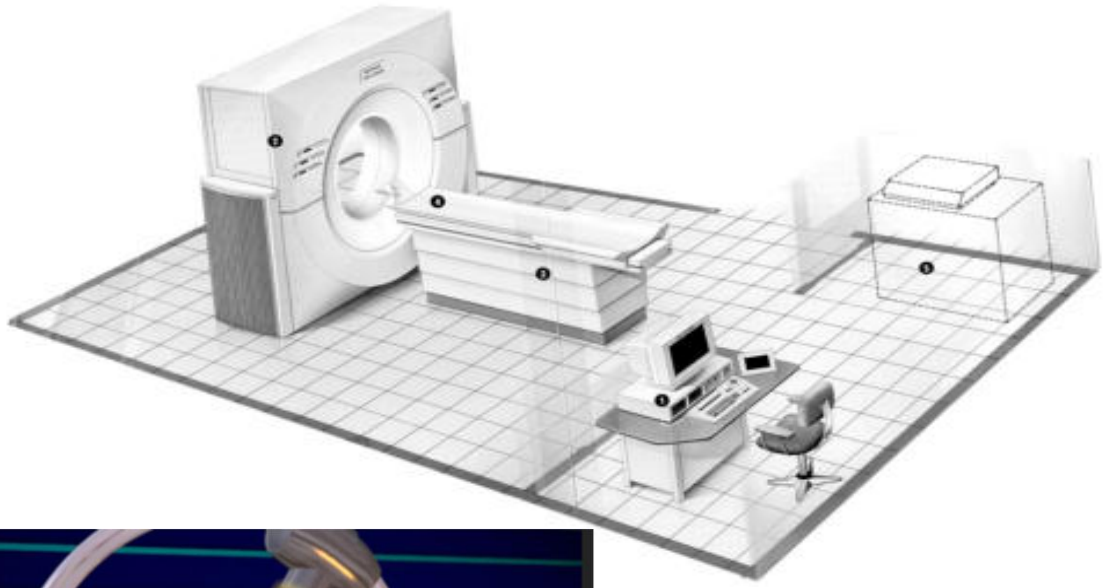
- **BASIC PRINCIPLE:**
  - The main principle behind the Computed Tomographic (CT) scanning is passage of an X-ray beam with a predefined thickness (collimation), through the patient that rotates around a center within the scanned level giving an image of a "slice" at which the scan is done
  - **The CT image/scan/cut**:
- The CT image is formed of adjacent small pixels that are arranged inside a matrix made of rows and columns, with each pixel (or more precisely voxel) having a certain grey-scale value corresponding to the tissue density present at this point in the scan
- The densities of the pixels are measured quantitatively and value is quantified in Hounsfield units (HU)
- The least HU value is of Air (negative values), and the highest are of calcium, barium, iodine and metals (hundreds and thousands)
- The higher the number of pixels in the scan (matrix size), the higher the spatial resolution (ability to identify 2 adjacent points as separate)





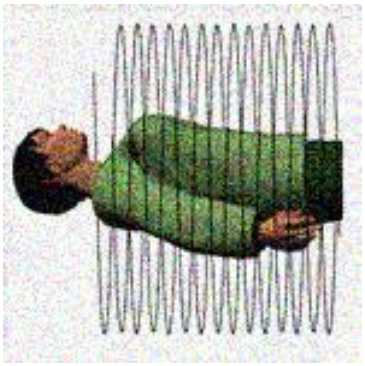


- **THE CT SCANNER SYSTEM:**
  - **X-ray tube**: Is the source of the beam
  - **Detector array:** Radiosensitive component that detects the intensity of the x-ray beam emerging from the imaged structure/level
- NB : The Tube and detector row are coupled opposite one another and rotate as one unit around the patient
  - **Gantry:** Is the aperture through which the patient passes It contains the tube – detector unit
- NB : Gantry tilt – is the angle at which the gantry containing the tube – detector system tilts giving rather oblique levels than the principle axial plane (axial oblique or coronal with tilting of the scanned part e g head)
- Gantries of the modern Multislice CT scanners (16 and 64 detector rows) are fixed with option of gantry tilt (oblique views are acquired through reconstruction techniques – see below)
  - **Table:** Is the unit upon which the patient lies The table passes through the gantry in or out moving the patient along the Z-axis of the CT system (the gantry height and width being the X and Y axes respectively)
  - **Console:** Is the operator panel containing the main processing unit, control system for patient exposure, scan parameters, as well as display for the imaged cuts
  - **Workstation:** Is a separate computer unit which is the powerhouse for the post-processing techniques .

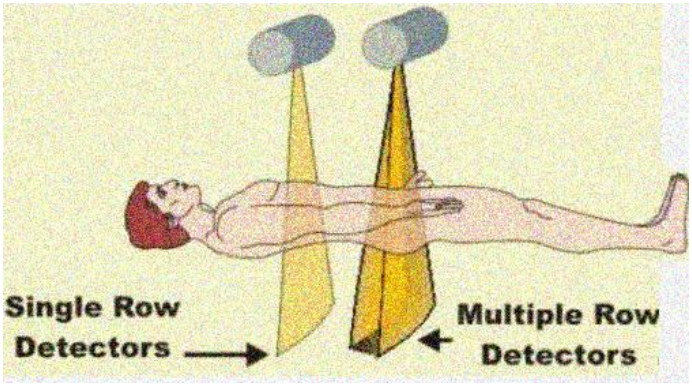


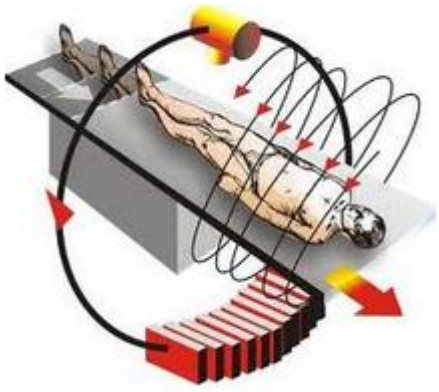
- **CONCEPTS OF CT IMAGING:**
  - First of all note has to be made of presence of 2 modes for CT scanning:
    - **Axial/Sequential scanning** (Non-helical systems):
      - Every scan is done by using a complete single rotation, then the table moves by a predefined distance (slice interval), and the next scan is done after a pause (tube delay)
      - This mode is relatively slow, not allowing for fast modes of scanning and related CT applications

    - **Volumetric/Spiral scanning** (Helical systems)**:**
      - The scan is done using a non-stop tube rotation (thanks to slip ring technology), where the table also moves continuously with a speed relevant to the rate of tube rotation (table pitch), giving an "orange peel" sort of scan, i.e. volumetric scan, which can be further used to be reconstructed using a workstation
      - This mode is faster than the conventional Sequential/axial scan, giving way to advanced CT techniques, and allowing for acquisition of image volumes that can be further processed giving more details and imaging capabilities
      - **Helical CT:**
        - ✓ Low dose of CM + better conc.
        - ✓ Increase resolution + decrease motion artifact
        - ✓ Short scan time + longer examination coverage + no interval (small lesion not missed)(obtain volumetric data & MPR, 3D, MIP)



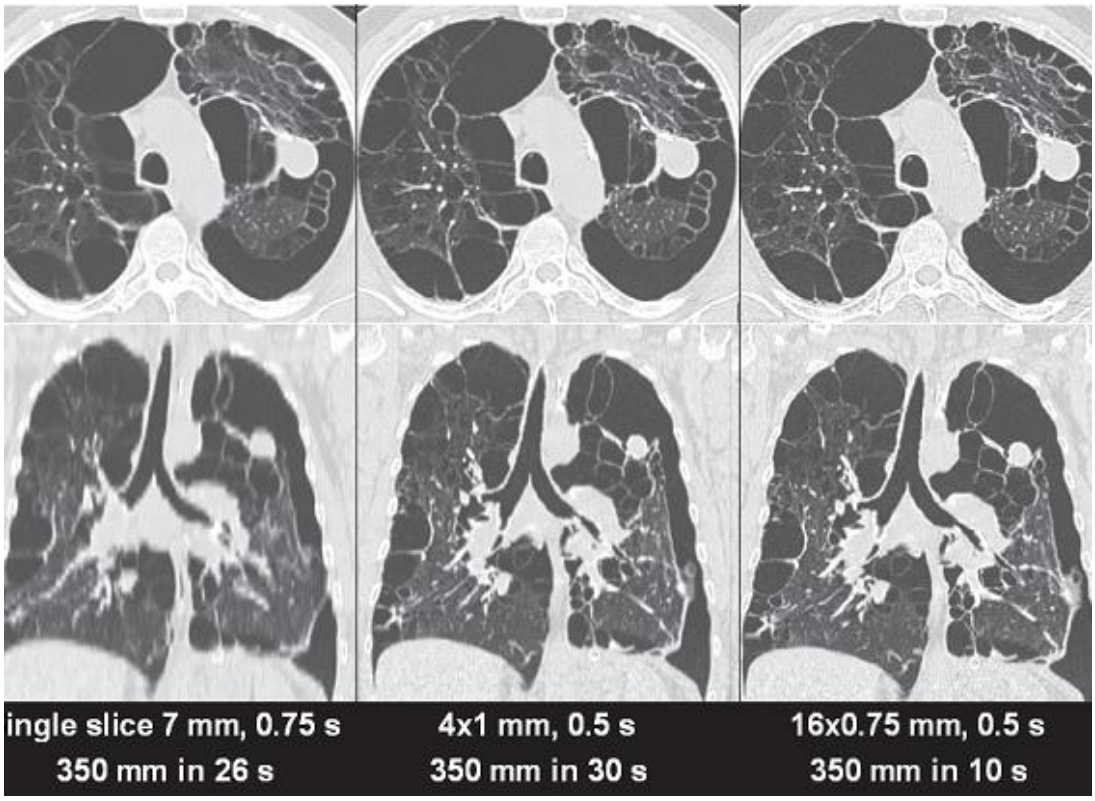
      - **Multislice/Multidetector CT systems (MSCT/MDCT):**
        - ✓ Newer generations of Helical CT systems where the detectors are arranged in rows parallel to each other allowing for acquisition of more than 1 slice per 1 tube rotation
        - ✓ Further increase of the scan speed, with no compromise of the spatial resolution
        - ✓ Moreover, further reduction of slice thickness can be achieved without prolonging the scan time, which allows for better and more effective post-processing techniques.





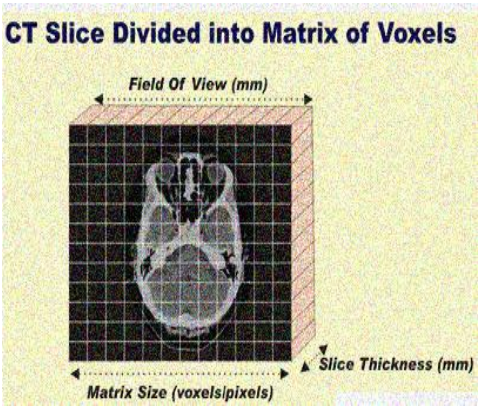
	SS spiral CT	MSCT (gantry rotation time)
Scan Range	• *Insufficient covering with single breath hold* • *Ideal isotropy only with limited scan range (overlap)*	*Extended scan range (imp for CTA, oncological study)*
Scan Time		*Shorter scan time (helpful in cooperative patient, pediatric cases, ...)*
Resolution	*Wide collimation >> missing spatial resolution on Z axis*	*Improved longitudinal resolution (Better collimation 1.25, 1, 0.625 mm) good for all 3D post processing*

- ***8 S*** *>> collimation down to 1 mm*
- ***16 S*** *>> below 1 mm now up to 320 S CT*
  - *Improved temporal resolution due to shorter gantry rotation time*
  - *Submillimetric longitudinal resolution*
  - *Single breath hold imaging*

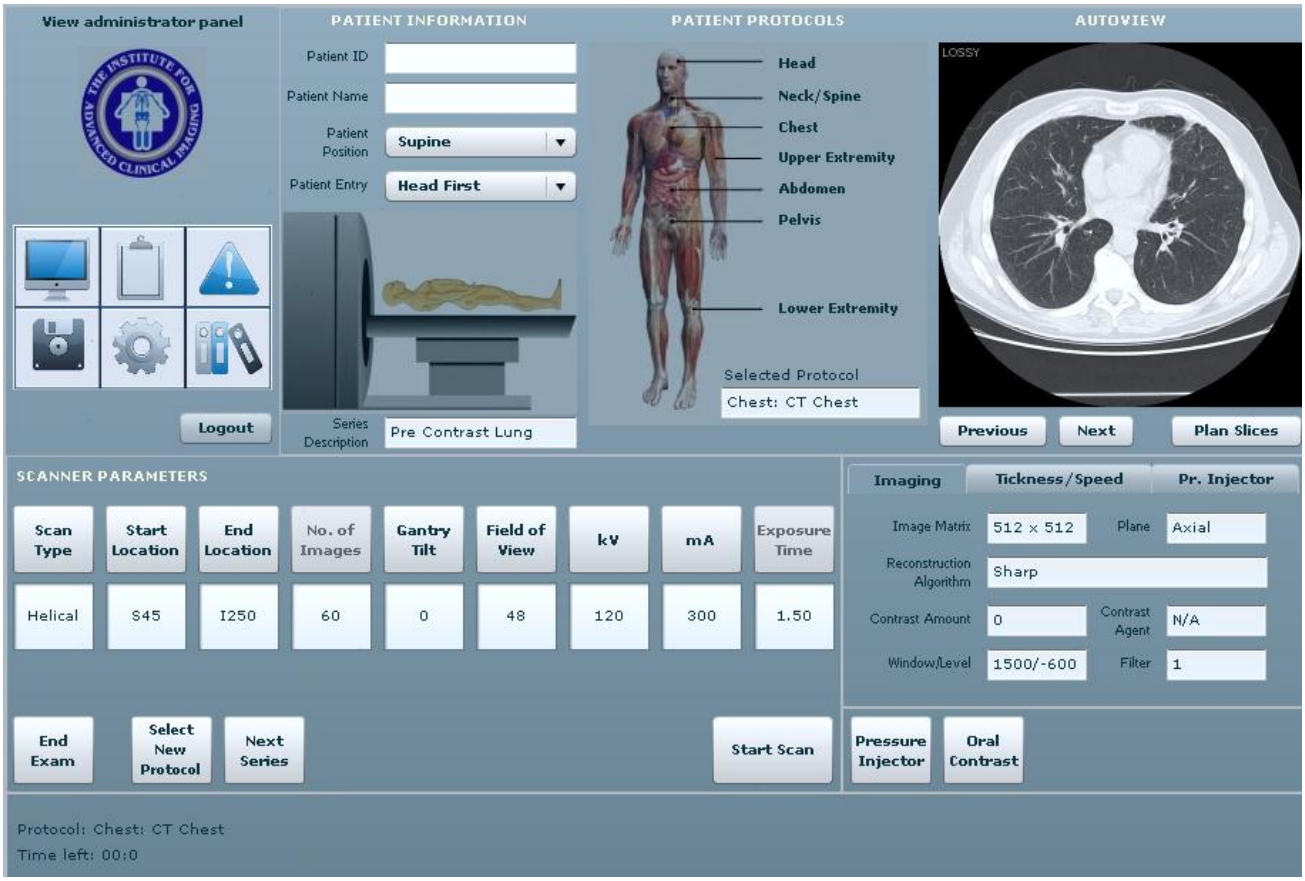


- **IMAGE QUALITY AND SCAN PARAMETERS:**
  - ✓ Image quality of CT images depends on both the scanning parameters, and the efficacy of post-processing techniques of the helical/MDCT systems
  - ✓ Scanning parameters: These are the parameters used for obtaining the final scans
  - ✓ Scanning parameters of Axial/sequential systems differ than those of the modern Helical scan based systems in the parameters related to the slice acquisition, and table motion. However they have common parameters related to patient factors ,Follow me:
    - **General parameters:**

1. Patient position on table: Prone – Supine – lateral decubitus
2. Proceeding part into the gantry: Head first – Feet first
3. Scout: Is the preliminary planar image taken to view the patient and allow for applying the levels of the scans: the start and finish Usually 2 scout views are acquired: AP and lateral
4. Start/end levels: A marking line that shows the beginning and end of the axial cuts
5. Field of View (FOV): Is diameter of the scanned section, it can be controlled by defining the width of the scan on the scout view
6. Matrix size: is the number of picture elements (pixels) present in the scanned cut The higher the matrix sixe the higher the resolution (256 x 256 had lower resolution than 512 x 512)
   - NB : In order to improve the resolution of the scan reducing the FOV to the limits of the scanned organ, and increasing the matrix size are the most important parameters, e g : Scanning for the sells requires a small FOV and a large matrix size, whereas scanning for the abdomen requires a larger FOV, and a smaller matrix size

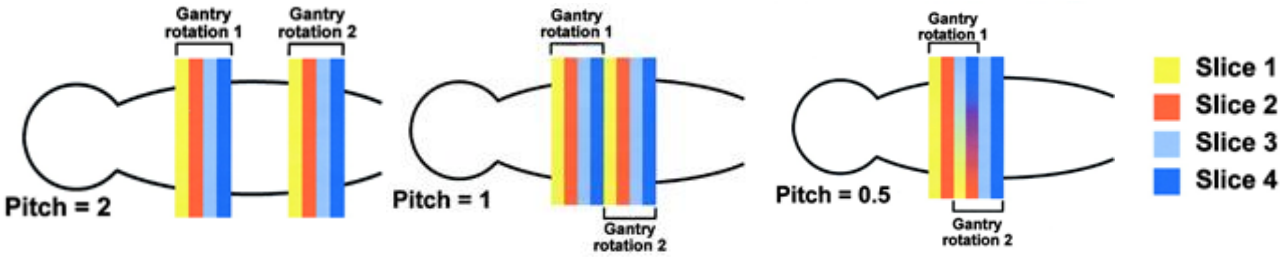


7. Exposure values (kVp and mAs): relatively higher than on conventional planar imaging techniques however a range of 120 – 140 kVp, and 80 – 250 mAs are used generally.



○ Specific parameters for axial scan:

1. **Slice thickness**; refers to the width of the X-ray beam which defines the thickness of the scanned level, Can also be termed "beam collimation"
2. **Slice interval**: refers to the distance which the table moves before acquiring the next cut
    - NB : Slice overlap – occurs when the slice thickness is less than the slice interval

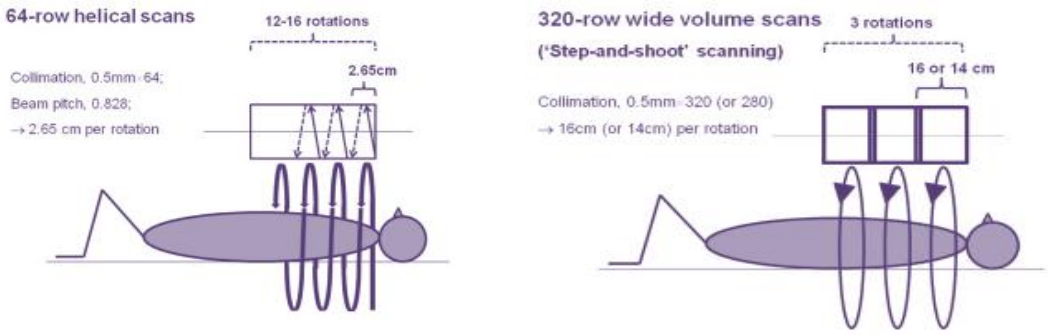


3. **Tube delay**: is the time pause taken between the sequential scans (required for tube cooling

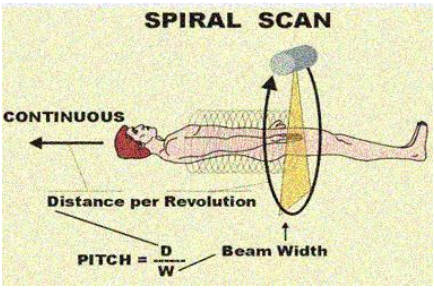
○ Specific parameters for volumetric scan:

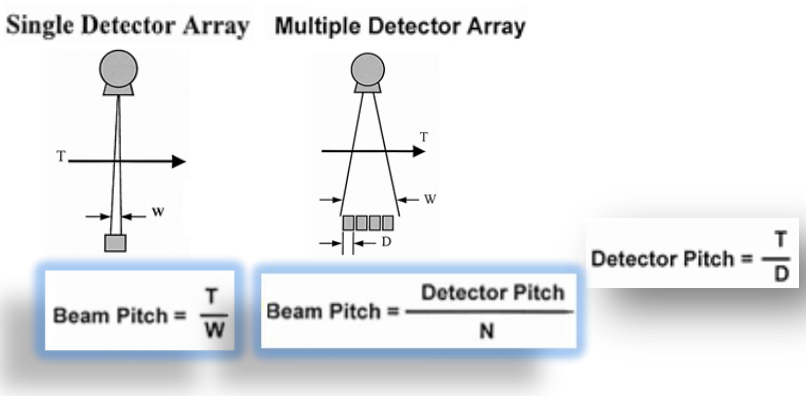
1. **Beam collimation**: refers to the final width of the beam which defines the slice thickness
    - NB : In MSCT the beam collimation is the total width of the beam However the slice thickness depends on the allowed detector rows available for the collimated beam e.g. if we use a beam collimation of 2.5 cm falling onto 4 detector rows each has 0.625 cm width then we have 4 slices each with 0.625 cm
    - The format used for beam collimation is written as an equation "Thickness of the detector row X number of rows"

e.g. "0.625 X 4"



2. **Gantry rotation**: Is the time taken by a single full rotation of the x-ray tube
3. **Table increment**: is the distance the table moves per gantry rotation
4. **Helical pitch**: is the table travel per rotation (table increment) divided by the collimation of the x-ray beam .
    - The higher the helical pitch the more compact the spire/volume is (better reconstruction possibilities "Decreased slice thickness").
    - The lower the helical pitch the wider the scan spire (poorer reconstruction image quality)
        - NB : the helical pitch affects both the patient exposure and scan time: the higher the pitch the shorter the scan time, and the lower the patient exposure dose "provided that other parameters are constant"





- ## POST-PROCESSING IN CT:

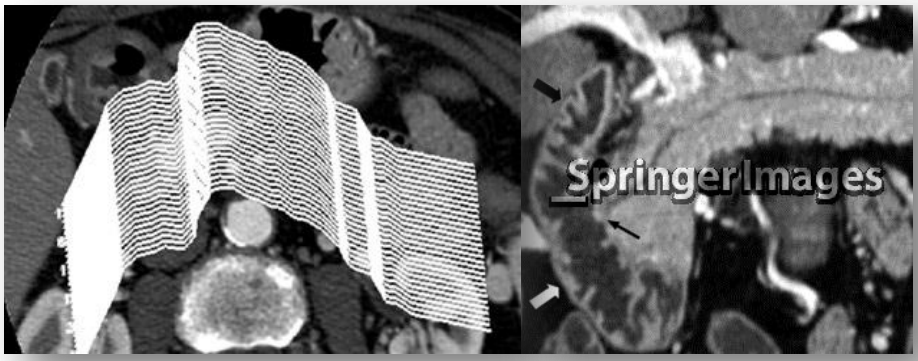
Post-processing refers to the process by which the acquired scan data are gathered into a single volumetric data set which is furtherly used to reconstruct the volume using one of the following techniques:

1. Multiplanar reformat (MPR):

- The method by which the data are used to generate the image in one of the 3 principle planes (axial/coronal/sagittal), or oblique planes of the principle planes
- "Isotropy": refers to the condition where the 2 dimensions of the pixel (voxel) at the scan plane equal the thickness of the scanned cut Isotropy is achieved when the thickness of the cut = 0 5 mm
- Isotropy allows reconstruction of the images with resolution same as that of the axial plane (in-plane resolution)

2. Curved planar reformat (CPR):

- Variant of MPR where the plane of reconstruction is defined by the user as a freely drawn plane
- Example: CPR drawn by tracing the ureter viewing its whole course



3. Maximum intensity projection (MIP):

- Method where all the voxels with high CT density (number "threshold" of which is defined by user) are shown as a 2 dimensional projection
- Picture shows the bones and high density contrast, which necessitates removal of the bones within the projection manually (Bone removal), in order to view the contrast filled cavities clearly without bone overlap
- Method used to make Angiographic images in Vascular imaging, IVU like imaging for ureter filled contrast, and Enteroclysis like images for GIT filled contrast

4. Minimum Intensity Projection (MinIP):

- The opposite of MIP where the imaged voxels are those of low (air) density
- It is used to image air containing structures, such as airways (bronchi and trachea), or air filled GIT.

5. CT Rendering Techniques: include Surface and volume rendering

- *Surface rendering (Shaded surface rendering) SSR:* Technique based on acquisition of the volumetric data having a value above a user defined threshold value, then transforming them into a 3D image in grey-scale and applying light effects to increased 3D reality

- *Volume rendering (VR):* relatively more complicated processing technique that uses more computer power than all of the above, where all the data within the volumetric set are acquired then 3D image is formed where each range of density values is given a color and transparency values, and finally lighting effects are applied

General scheme for CT.....

Definition

1. Indication
2. Contraindication
3. Advantages & Disadvantages

4. Patient preparation
5. Contrast media
6. Technique

- Patient position
- Scout
- Localizer (post-scout)
- Field of view
- Slice thickness & interval
- Exposure factors: KV, Ma
- Scan time, delay

7. Aftercare
8. Complication
9. WW,WL+Filming & post-processing
10. Normal finding

Definition:

1. Indication: vitamin ACDE

- V: Vascular
- I: Inflammatory (infectious & non-infectious)
- T: Trauma
- A: Autoimmune
- M: Metabolic
- I: Idiopathic/iatrogenic
- N: Neoplastic
- A: Acquired
- C: Congenital
- D: Degenerative
- E: Endocrine

cervical spine	lumbosacral
Vitamin..... (I: iatrogenic: post myelography) **+** **A** **C:** Congenital anomalies **D:** Degenerative disease, UL pain **E:**	**vitamin** **+** **A** **C:** **D:** Degenerative disease, Low backache +sciatica / radicular Pain **E:**

BRAIN	ORBIT	SELLA	TEMPORAL	PNS
Best indication is in emergency, **otherwise MRI is better** **V:** AVM, CV Stroke **I:** **T:** Trauma(PC) **A:** **M:** **I:** FUP postoperative **N:** FLs, Tumor (MRI is better) **A:** ▪ Persistent headache ▪ Convulsion ▪ Increase ICT(DCL) **C:** **D:** **E:**	Assessment of orbital content **V:** **I:** **T:** FB **A:** **M:** **I:** **N:** Retinoblastoma, MM, ON glioma **A:** **C:** **D:** **E:**	**V:** **I:** **T:** **A:** **M:** **I:** **N:** ▪ Cl/p of pit tumor (micro, macro adenoma) MRI is more sensitive in pit micro adenoma ▪ **Visual field defects** (optic chiasm compression) ... temporal hemianopia ▪ **Radiological indication**: widened Sella by XR **A.C.D** **E:** ▪ Hyperprolactinemia ▪ Acromegaly, Dwarfism ▪ DI	**V:** **I:** **T:** Trauma **A:** **M:** **I:** **N:** Cholesteatoma Acoustic neuroma Glomus jugular Tumor **A:** Tinnitus, vertigo **C:** **D:** **E:**	**V:** **I:** sinusitis, polyp **T:** Trauma **A:** **M:** **I:** Post-operative **N:** Tumor **A** **C:** **D:** **E**

NECK	CHEST	ABDOMEN	PELVIS
V: I: Sialadenitis T: A: M: I: N: Tumors of pharynx, larynx Abnormal LNs in neck A: C: D: E:	V: Hemoptysis I: Lung abscess T: A: M: I: FUP post-operative N: ➢ Bronchogenic carcinoma ➢ Hilar, rounded shadow on x-ray ➢ Mediastinal mass/ LN A: C: D: E:	V: Hematemesis/melena/BPR Aneurysm, IVC thrombosis I: Hepatitis, pancreatitis ,… T: Blunt, penetrating Trauma A: M: I: N: ▪ Benign, Malignant tumors ▪ Evaluation of known/suspected mass/fluid…cirrhosis, obstructive jaundice ▪ Classification of finding from other imaging modalities US, XR ▪ TTT planning for radiation therapy (i e tumor staging) ▪ Therapeutic: CT guided intervention A: C: Congenital anomalies D: E:	V: I: Pelvic collection/ inflammatory process T: Pelvic trauma A: M: I: N: Pelvic tumors ✓ UB ✓ uterine ✓ ovarian ✓ Anorectal A: C: D: E:

2. Contraindication:

- Contraindication to x-ray exposure: pregnancy
- Contraindication for CM: non-fasting, allergy, renal impairment
- Contraindication to technique: irritable pt
  sepsis at injection site,
  not diagnostic (Relative contraindication)as emergency, acute abdominal trauma, acute renal colic)

3. Advantages & Disadvantages:

Advantages:

1. Completely eliminates the superimposition of images of structures outside the area of interest
2. Differentiate bone, hemorrhage, soft tissue due to inherent **high-contrast resolution of CT**, differences between tissues that differ in physical density by less than 1% can be distinguished
3. Excellent **spatial resolution(0.3-1mm)**.....CT>MRI
4. **Multiplanar reformatted** imaging capabilities: data from a single CT imaging procedure can be viewed as images in the axial, coronal, or sagittal planes.
5. **Faster** image acquisition especially with MDCT
6. **New techniques application** as
   - CT angiography avoids the invasive insertion of a catheter
   - CT Colonography (also known as Virtual Colonoscopy) may be as useful as a barium enema for detection of tumors, but may use a lower radiation dose
7. Relatively **Low cost**

Disadvantage:

- **X-ray exposure** "CT is regarded as a moderate- to high-radiation diagnostic technique".
- Often requires **high dose of contrast** (oral -IV) with their side-effects.
- **Streak artifacts** from metallic objects

4. Patient preparation

- Fasting if CM to be used to avoid vomiting, aspiration(4hs...children,6hs.....adult)
- Sedative if irritable, uncooperative patient
- Enema & drinking CM if GIT technique (CT pelvis)
- Premedication if required
- S.Creat. ... if contrast is needed

5. CM: 2 amp (3 amp in pelvis)

- **IV: urograffin (ultravist in case of contraindication, allergy,...)**

  Indication
  - Not mandatory (only used in suspected tumor / inflammation) in spine / PNS
  - Mandatory: Orbit, Sella, Temporal bone?, (brain: AVM)
  - Not used in
    - ✓ Brain in clinical setting of: stroke, PC, he
    - ✓ Stone protocol

  Dose & Rate
  - In **pelvic study** one amp is taken 1/2 an hour before exam to opacify UB
    - (in cancer UB DON'T inject before exam)
  - **In neck scanning** being very vascular... 1/2 of cm at start of exam, 1/2 at middle of exam
- **Oral & rectal (GIT): gastrograffin (~~barium~~: high density causing artifacts)**

  4 cups of GG
  - 3 cups 1h before exam to show intestine
  - 1 cup just before exam to show stomach, duodenum as it's rapidly emptying

  GG Enema

6. Technique:

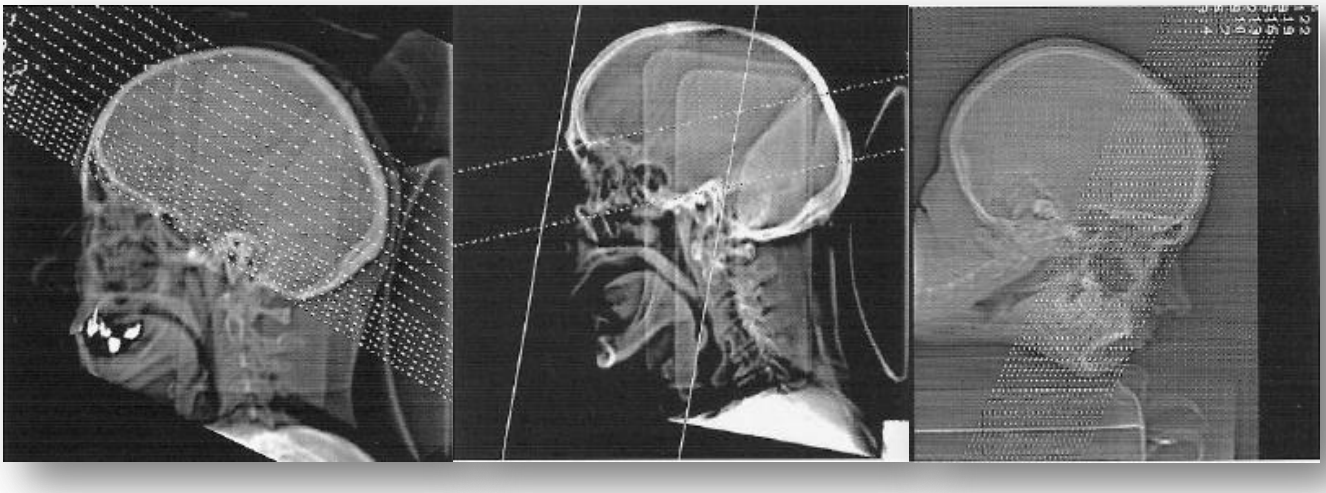
- **Patient position**
  - ✓ Patient position on table: Supine (prone if PNS, Biopsy)... *arms above head in CPA study*
  - ✓ Proceeding part into the gantry: head 1st (feet 1st only in LL examination, scannogram)
  - ✓ Cuts: axial (coronal only in POTS)
- **Scout**
  - ✓ **AP:** CPA
  - ✓ **Lateral:** H&N, LSS (Tilt parallel to disc space)
- **Localizer(post-scout):**
  - ✓ **Start and finish**
  - ✓ **Tilt in B/POTS** (brain: tilt parallel to skull base)

    (PNS: inverse rotate images on coronal cuts (patient is prone)

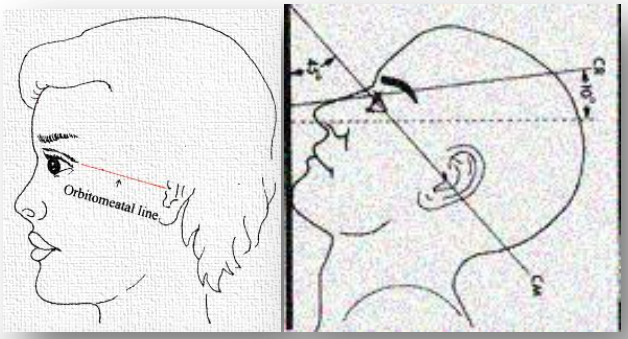
1. **Cervical spine**: from skull base to c7 parallel to disc space/according to required level
   LSS: from L3-S1 parallel to disc space/according to required level
2. **Brain**: from skull base to vault parallel to canthomeatal line
3. **Sella**:
   - axial...parallel to orbitomeatal line to cover sella above clinoid process
   - Coronal: 5mm in front of the sella till floor of 3rd ventricle
4. **Orbit**:
   - axial... from inferior to superior orbital margin
   - Coronal: front of orbit till the sella

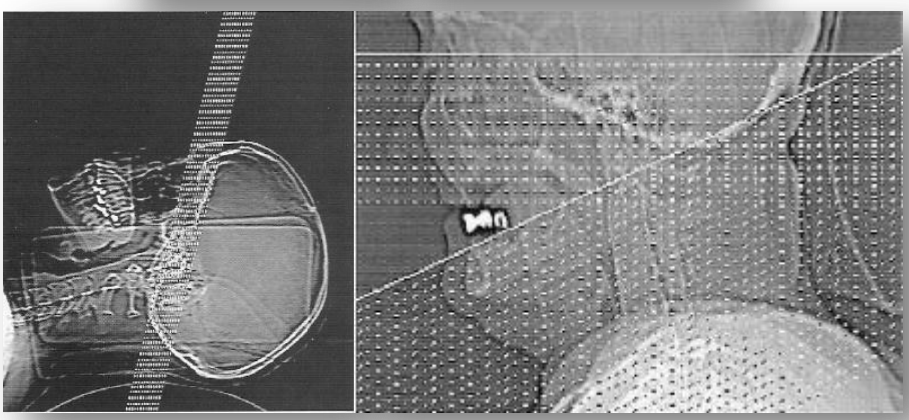
5. **PNS**:
    - axial… floor of maxillary sinus till roof of frontal sinus
    - Coronal……frontal sinus till end of sphenoid sinus
6. **Temporal**:
    - Axial… from inferior to superior of petrous bone
    - Coronal: from anterior to posterior petrous bone
7. **Neck**…
    - fromc1-c7 (nasopharynx to upper chest)perpendicular to air column
    - In case of parotid… EOM to lower mandible

8. **Chest**……above lung apex to lower end of costophrenic angle
9. **Abdome**n…dome of D to iliac crest(include lung bases in field)
10. **Pelvi**s… from iliac crest to end of SP



Brain Orbit Facial





Temporal Neck

- **Field of view** **(Images should be obtained with small scan FOV in smaller structures to optimize detail)**

Smallest.....Sella, Servical spine.....12

POTS (instead sacral spine LSS).....15

Neck.....18

Brain.....22

Chest.....30

PA.....35

- **Slice thickness & interval** (same as thickness except in)
  - ✓ 3D "overlap is needed",
  - ✓ HRCT chest... 2/10

	2mm	3mm	5mm	8mm	10mm
	Sella **Temporal**	**Cx spine** **Glands** ▪ **Parotid** ▪ **Pancreas, adrenal, stone protocol** ▪ **~~Lacrimal~~(orbit)**	**بواقى** ✓ **Neck** ✓ **Pelvis** ✓ ✓ **Post fossa** ✓ **POTS** **PNS** **(OMC...2mm)** ✓ **LSS**	**chest**	**Abdomen** **Brain?**

- **Exposure factors: KV, mA.....** 140-200
- **Scan time, delay...** 3 seconds except
  - ✓ Brain... 1sec
  - ✓ HRCT... 2 seconds

fast in dynamic scanning

- ✓ Dynamic scanning... taking successive images at different, same (early, delayed) levels in short time less than 5sec injection e g hepatic hemangioma every 5min up to 1/2 h to see ccc enhancement pattern
- ✓ Dynamic scanning is useful if suspecting microadneoma whereas normal pit enhance, while adenoma appears hypo dense)

7. Aftercare:

- Observe for CM reaction
- Renal dialysis if urgent CT with contrast in renally impaired pts.

8. Complication:

- XR exposure
- Contrast

9. Filming & post-processing:

- ✓ **Matrix size**: 256 except BOTS
- ✓ **WW,WL:**
  - **Soft tissue(PA,LSS)**.....50,250
  - **Bone**..... 250, 1500
  - **Extended bone**..... 400, 4000

  - **Brain**.....40,80 (140)
  - **Neck**..... 40, 200
  - **Mediastinum**..... 30, 300
  - **Liver**..... 60, 160
  - **Lung**..... - 600, 1200

Spine	Brain	Sella, orbit, PNS	Temporal
• BW • soft tissue window	• BW(in case of Mets, trauma) • soft tissue window ✓ 140/40 post fossa ✓ 80/40...rest of brain	• axial(no contrast) ... soft only • coronal(contrast) ... soft, bone	• axial(contrast)...soft, extended bone • coronal(contrast)soft, extended bone **contrast is a must?!**

Neck	Chest	Abdomen	Pelvis
• BW (if suspected bone destruction) • Soft tissue window (neck: 200/40)+c	• BW (if needed) • Soft tissue ✓ Med (300/30) ✓ Lung(1200/-600)	• Soft tissue ✓ 160/60... for liver ✓ 250/50...after end of liver to show Soft tissue especially kidney related	• BW... fractures • soft tissue window

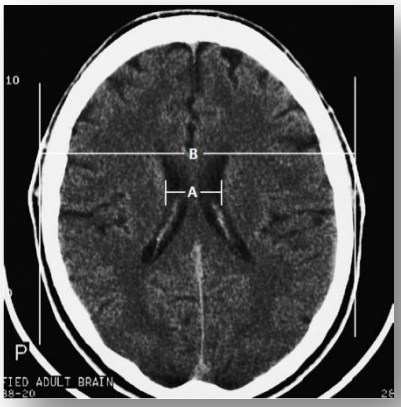
NB:
CT-pelvis.....undescended testis protocol
- Cuts every 5/5
- Feet 1st to minimize radiation hazards
- FOV...18(child)

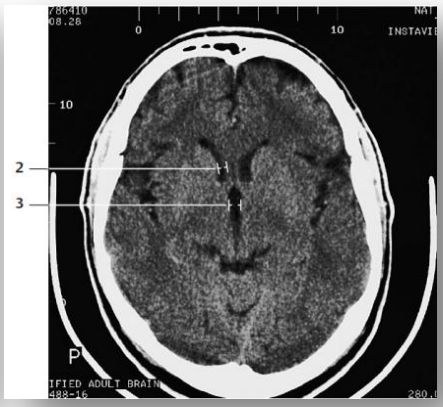
- ✓ **Filming:** BW, soft tissue window 20 images each
- ✓ **post processing...** as mentioned earlier

10. Normal finding :

I. BRAIN

1. **Normal attenuation values:**
   - ✓ White matter… Non-contrast: 39 HU…… Post contrast: 41 HU
   - ✓ Cortex…… Non-contrast: 32 HU…… Post contrast: 33 HU
2. **Ventricular dimension**



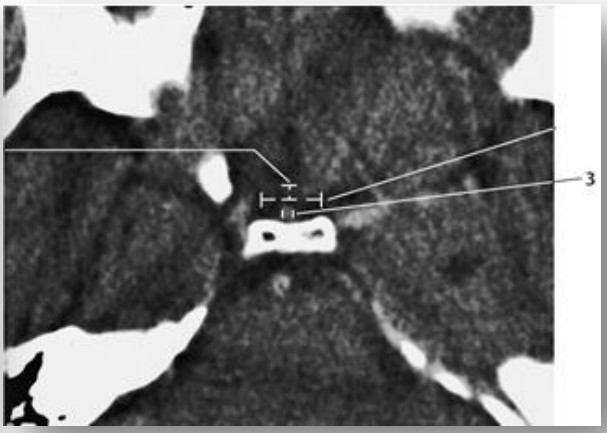


Cella media index:
B/A > 4 = normal

Frontal horn of lateral ventricle (at level of foramen of Monro):
- Under age 40: < 12 mm
- Over age 40: < 15 mm

Width of third ventricle:
- < 5 mm in children (slightly more in infants)
- < 7 mm in adults under age 60
- < 9 mm in adults over age 60

II. Pit.



Important Data: Pituitary:

a) Height (in the mid-coronal plane): 2–7 mm
- Pregnancy: up to 12 mm
- Puberty: up to 10 mm in girls, up to 8 mm in boys

b) Width (transverse extent in coronal plane, women of childbearing age): 12.9 mm ± 1.6 mm

3. Pituitary stalk:
< 4 mm

III. Orbit

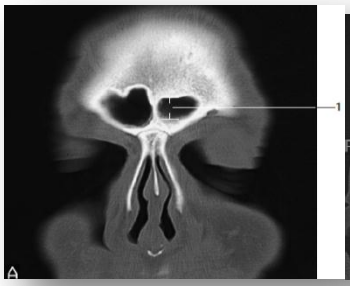
Lacrimal gland: less than half of the gland is anterior to the Fronto-zygomatic process.

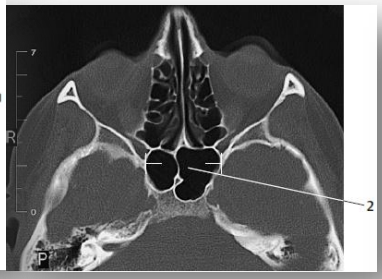
Position of globe:
Posterior margin is 9.9 mm ± 1.7 mm behind the interzygomatic line

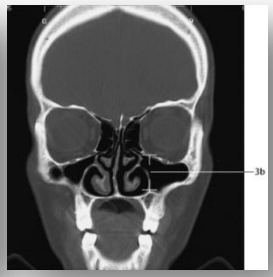
Optic nerve (axial plane):
a Retro bulbar segment: 5.5 mm ± 0.8 mm
b Narrowest point (at approximately mid-orbit): 4.2 mm ±0.6 mm

Eye muscles
a Superior rectus: 3.8 mm ± 0.7 mm
b Oblique: 2.4 mm ± 0.4 mm
c Lateral rectus: 2.9 mm ± 0.6 mm
d Medial rectus: 4.1 mm ± 0.5 mm
e Inferior rectus: 4.9 mm ± 0.8 mm

IV. Para nasal Sinuses







1 Frontal sinus:
! Height ca. 1.5–2 cm
2 Sphenoid sinus:
! Width 0.9–1.4 cm
3 Maxillary sinuses:
a Width ca. 2 cm
b Height ca. 2 cm

V. Petrous bone

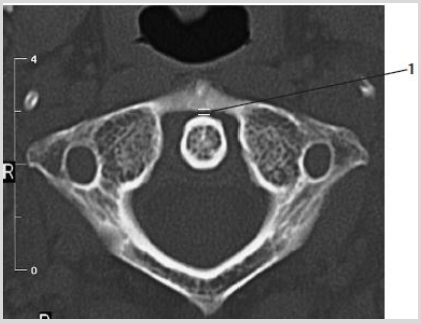
Internal auditory canal:
Approx. 5–10 mm, with ca. 1 mm difference between the right and left sides

Axial scan through the internal auditory canal

VI. spine

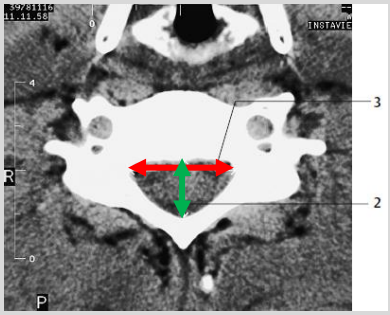
Cervical

1 Anteroposterior diameter of preodontoid space:
< 2 mm



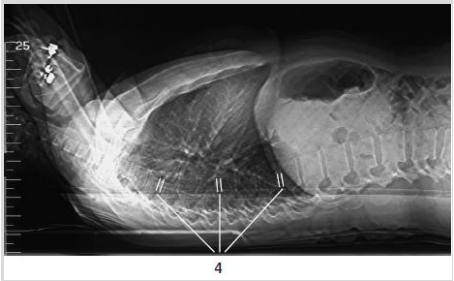
2 Sagittal diameter of spinal canal:
- C1 = 21 mm
- C2 =20 mm
- C3 =17 mm
- C4−C7 = 14 mm

3 Width of spinal canal:
Transverse diameter at level of pedicles > 2cm



Thoracic

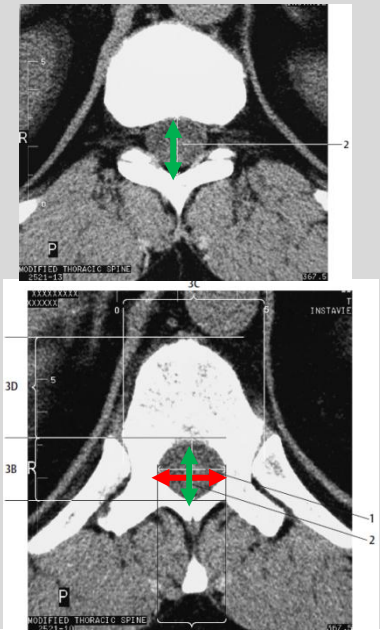
4 Width of intervertebral disk spaces:
- Smallest at T1
- T6−T11: ca. 4−5 mm
- Largest at T11−T12



2 Sagittal diameter:
- T1−T11 = 13−14 mm,
- T12 = 15 mm

1 Width of spinal canal:
Transverse diameter at level of pedicles > 2cm

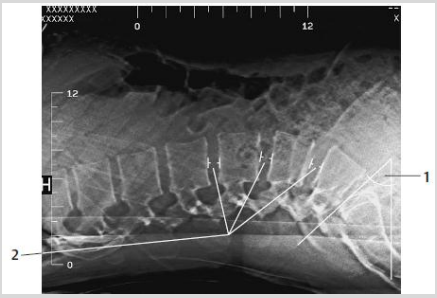
3…..Jones-Thomson ratio (= A×B/C× D):
Between 0.5 and 0.22 = normal
(< 0.22 = spinal stenosis)



Lumbar

1 Lumbosacral angle (S1/horizontal plane):
26−57°

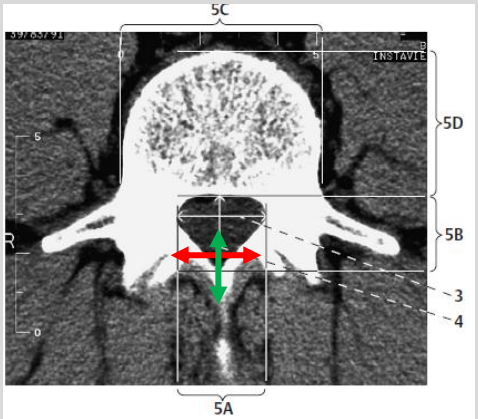
2 Width of intervertebral disk space or height of lumbar intervertebral disks:
Approx. 8−12 mm, increasing from L1 to L4/5, decreasing again at L5/S1



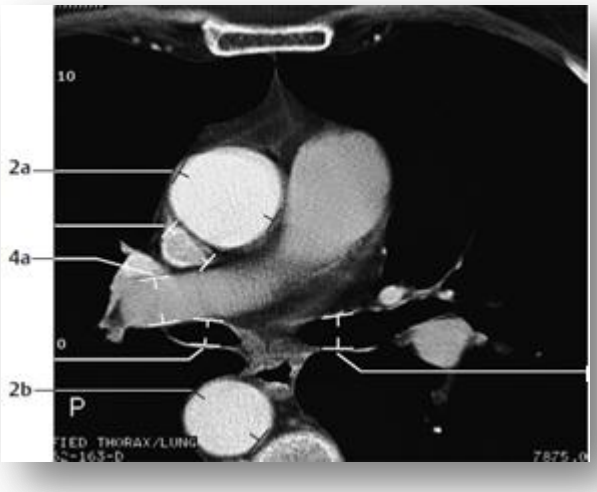
4 Sagittal diameter:
- 16−18 mm (simple formula: not less than 15 mm)
- 11−15 mm = relative stenosis,
- less than 10 mm = absolute stenosis

3 Width of spinal canal:
Transverse diameter at level of pedicles:
- ✓ L1−L4 > 2cm
- ✓ L5 > 24 mm

5……..Jones-Thomson ratio (= A×B/C× D):
Between 0.5 and 0.22 = normal
(<0.22 = spinal stenosis)



VI. Thorax



2 Diameter of aorta: < 4 cm

a. Ascending aorta:

- ✓ At level of pulmonary trunk bifurcation: 3.2 cm ± 0.5 cm
- ✓ At level of aortic root: 3.7 cm ± 0.3 cm

b. Descending aorta:2.5 cm ± 0.4 cm

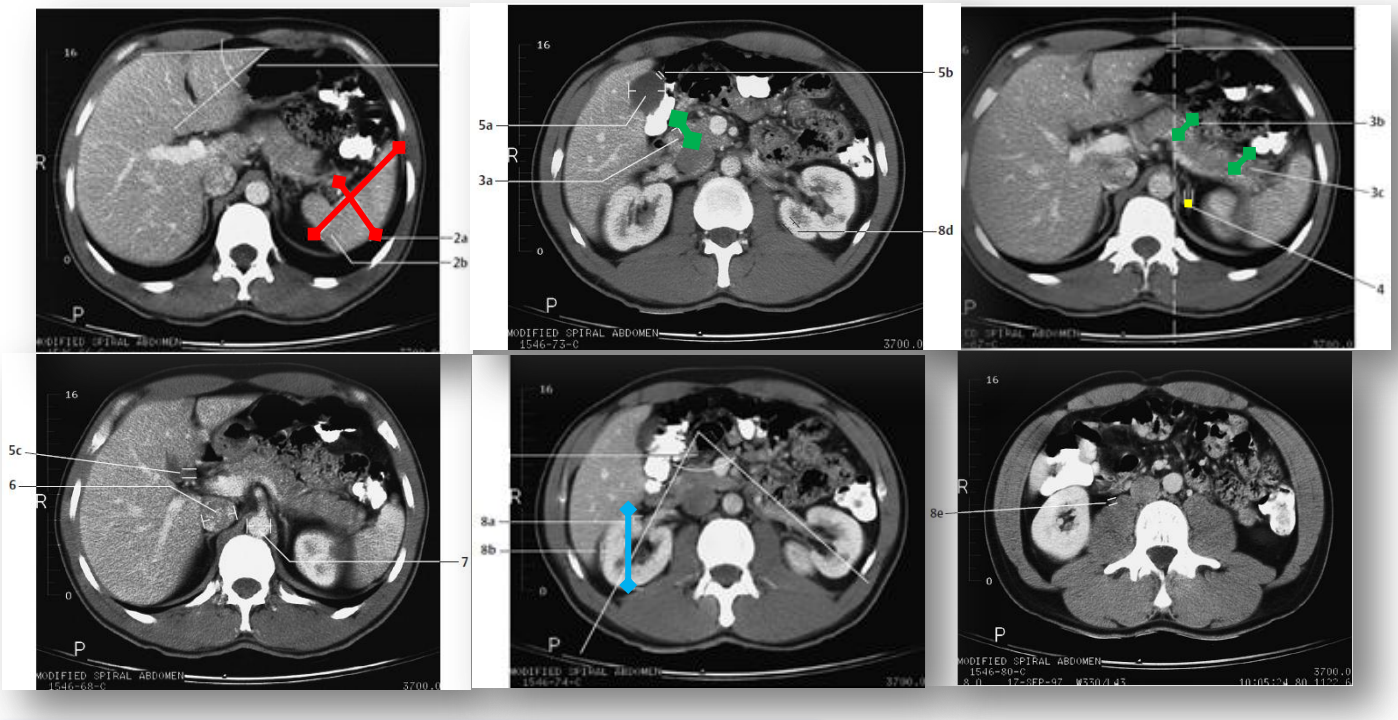
Aortic arch: 1.5 cm ± 1.2 cm

Ratio of ascending to descending aortic diameters = 1.5:1

4. Diameter of pulmonary arteries:

- Pulmonary trunk: 2.4 cm ± 0.2 cm
- Right pulmonary artery: 1.9 cm ± 0.3 cm
- Left pulmonary artery: 2.1 cm ± 0.4 cm

VII. abdomen



1. Liver:

Caudate lobe/right lobe (CL/RL) = 0.37 ± 0.16
(e.g., 0.88 ± 0.2 in cirrhosis)

2 Spleen:

a. Depth (D): 4–6 cm
b. Width (W): 7–10 cm
c. Length (L): 11–15 cm (reconstruction)

Splenic index: D×W×L = between 160 and 440

3. Pancreas:

a. Head up to 3.5 cm
b. Body up to 2.5 cm
c. Tail up to 2.5 cm

4. Adrenal glands (variable):

Crural thickness < 10 mm

5. Gallbladder:

a. Horizontal diameter up to 5 cm (> 5 cm is suspicious for hydrops)
b. Width of gallbladder wall:1–3 mm
c. Width of common bile duct:8 mm (after cholecystectomy:10 mm)

6. Inferior vena cava:

Transverse diameter up to 2.5 cm

7. Abdominal aorta:

Transverse diameter ca. 18–30 mm

8. Kidneys:

a. Anteroposterior diameter. 4 cm
b. Transverse diameter 5–6 cm;
craniocaudal diameter (= highest to lowest section) 8–13 cm
d. Width of renal cortex: 4–5 mm
e. Width of ureter: 4–7 mm

Position of superior poles of kidneys:

- Right: superior border of L1
- Left: inferior border of T12

- ✓ Time to Corticomedullary equilibrium:1 minute
- ✓ Contrast excretion into the pyelocalyceal system: 3 minutes
- ✓ Gerota fascia (thickness):1–2 mm

Lymph nodes larger than 1 cm are suspicious for pathology.

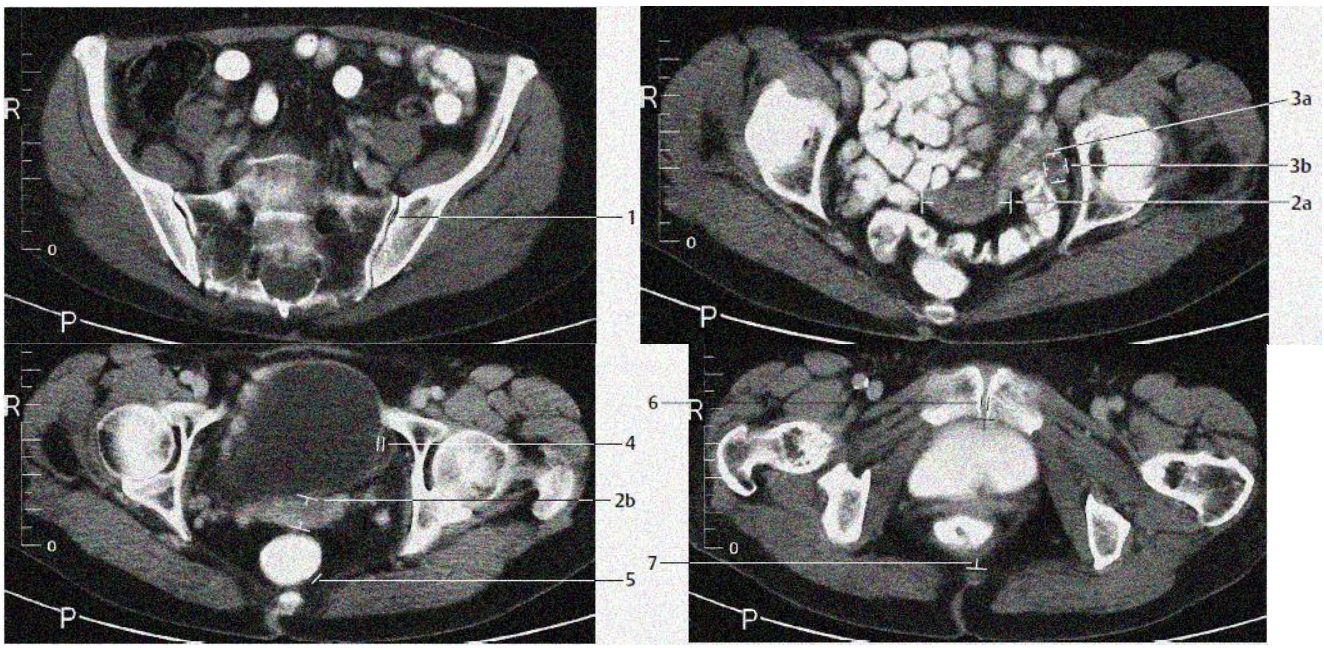
Attenuation values:

- Liver: 65 ± 10 HU
- Spleen: 45 ± 5 HU
- Pancreas: 40 ± 10 HU
- Fat: -65 to -100 HU

- Kidneys: 30–45 HU without contrast medium;
  renal cortex after contrast medium: approx. 140 HU
- Adrenal glands: 25–40 HU without contrast medium

- Muscle: 45 ± 5 HU
- Blood vessels: approx. 40–55 HU without contrast
- Gallbladder contents: 0–25 HU

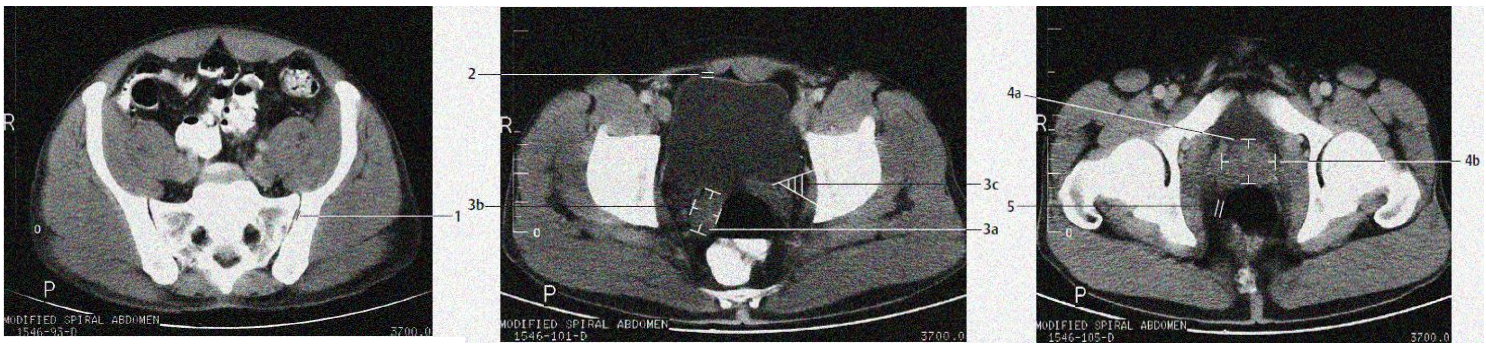
VIII. female pelvis



4. Urinary bladder:
Wall thickness (of well-distended bladder): = 3 mm

5. Rectum:
Wall thickness = 5 mm

IX. Male pelvis



1. Sacroiliac joint spaces:
Width 2–5 mm (anterior and inferior: 2–3 mm)
2. Urinary bladder:
Wall thickness (of well-distended bladder): = 3 mm
3. Seminal vesicles: Size (highly variable):
a. Length up to 5 cm
b. Width up to 2 cm, height up to 2.5 cm
c. Angle between bladder and seminal vesicle: clear on each side
4. Prostate:
Size (varies with age, 20–70 years):
a. Anteroposterior diameter 2.5–3 cm
b. Lateral (and craniocaudal diameter) 3–5 cm
Attenuation value: 40–65 HU
5. Rectum:
Wall thickness ! 5 mm

	virtual CT Tracheography	virtual Gastroscopy	Virtual Colonoscopy	Virtual HSG
Def.	Visualization of **tracheobronchial tree** e' MDCT	Visualization of **stomach** e' MDCT	Visualization of **LI** e' MDCT	Novel non-invasive diagnostic modality combines HSG with MDCT for assessing **uterus, FT** based on volumetric HRCT data improved visualization of uterine cavity Assess: ▪ Uterine cavity, morphology patency of tubes ▪ External morphology of uterus ▪ other pelvic structures
Indicat-ion	1. **Failed or #** to conventional bronchoscopy 2. **Tracheobronchial tree abnormality** : ✓ Inflamm … bronchiectasis ✓ Tumor: bronchogenic C ✓ Stricture… its extent	1. **Failed or #** to conventional Upper GI endoscope 2. **Suspected gastric disease**: ✓ Indigestion ✓ Epigastric pain ✓ Oes. Reflux 3. Detection staging of **gastric tumors** 4. Evaluation of early, advanced gastric carcinoma, leiomyoma, lymphoma, and benign ulcer	1. **Failed or #** to conventional Colonoscopy (due to redundant loops, hernias, masses and malrotation) ▪ **Patients unwilling** to undergo routine or follow-up colonoscopy due to discomfort/phobia/IV sedation etc. 2. **Colonic**… ✓ Polyp ✓ Tumor ✓ Mass 3. **Screening** individuals at high risk for colonic cancer	عقم.....infertility "The primary use for virtual HSG, as for conventional HSG, is in the diagnostic work-up for female infertility" سقط..... repeated spontaneous Abortions رحم ضايع... ccc of uterine Malformation العملية فى..... ✓ Pre-operative ✓ Post-surgical mass in patient e' history of leiomyoma
Contra-indication	• #…to XR • #…to CM	Patient e' with previous barium study…wait **1wk**	Patient e' with previous barium study…wait **2wks**	• Pregnancy • Active pelvic infection

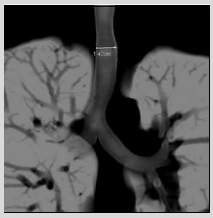
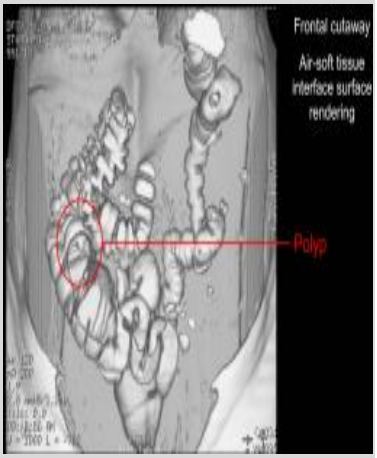
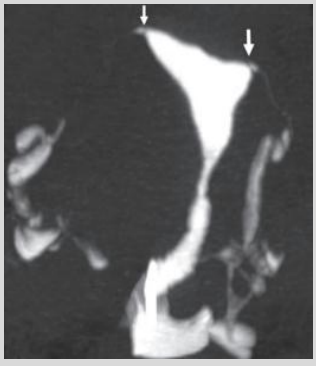
Advantage	1. Non-invasive 2. Better patient acceptance and tolerance ▪ No anesthesia 3. Accurate, sensitive.	It allows visualization of extramural soft tissue, other structures and their relations to the surrounding organs	***Patient:*** 1. Non-invasive 2. Better patient acceptance and tolerance ▪ Preparation is simple compared to colonoscopy "If faecal tagging is further developed, current bowel preparations could be Circumvented" ▪ No IV sedation required ▪ Can return immediately to work or home 3. Less costly ***Clinically:*** Allows review of entire abdomen and pelvis:- potentially lifesaving discovery of asymptomatic conditions is possible (e.g. AAA/RCC) **Accuracy** ✓ Highly accurate and reproducible ✓ Sensitivity > 90% (in many studies even better than conventional colonoscopy!!!!!!) **Safety** Lower risk of procedural complications e.g. perforation, bleeding) ***Radiologically*** It provides three-dimensional images that can depict many polyps and other lesions as clearly as when they are directly seen by optical Colonoscopy. **Visualization of entire colon** ✓ Explore beyond colonic obstruction and both sides of haustral folds ▪ Does not suffer from superimposition of structures (unlike BE) ▪ Visualizes peri-colonic tissues **Fast examination** - performed in less than 10 min.	1. Non-invasive 2. Better patient acceptance and tolerance.....No cervical clamping Lower risk of procedural complications **High resolution isotropic image** provide detailed assessment of 1. Uterus, tubes..... virtual HSG may prove to be superior to other noninvasive modalities for evaluating tubal patency 2. Endoluminal view of cx canal, endometrial cavity. 3. Evaluate extra uterine pathology.

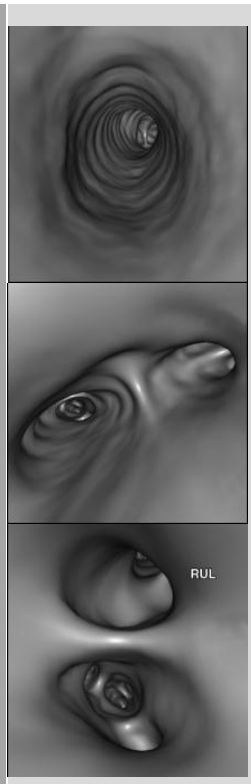
Dis-advantage	***Diagnostic:*** ***Therapeutic:***	***Diagnostic:*** ▪ **Preparation** It needs proper patient preparation (gaseous distension of the stomach) ▪ **Sensitivity** Inability to reveal small and superficial mucosal lesions ▪ **Specificity** ▪ **Pitfalls** ***Therapeutic:*** It is time consuming and finally inability to obtain samples for histopathologic assessment	***Diagnostic:*** ▪ **Preparation** Still requires bowel prep ▪ **Sensitivity** Less sensitive than colonoscopy for detection of small polyps less than 1 cm. ▪ **Specificity** Specificity was low (until now), due to residual bowel fluid, fecal residue. ▪ **Pitfalls….**False Positive Main culprits are residual fecal material and fluid due to incomplete bowel prep. - Scanning both supine and prone: exclusion of shifting material. - IV contrast: exclusion of non-enhancing material. - Fecal tagging: exclusion of enhancing material. ***Therapeutic:*** CT Virtual Colonography is strictly a diagnostic Procedure "Not therapeutic" (Biopsy and polypectomy cannot be performed)	***Diagnostic:*** ▪ Cost!! ▪ Non-available ***Therapeutic:*** Not therapeutic… inability to perform immediate tubal cannulation in case of proximal tubal occlusion
complication	▪ XR exposure in pregnancy ▪ CM…allergy			"Extremely rare" **1) Non-invasive** ✓ low risk of bleeding/ infection because no clamping or retraction of the uterus or occlusion of the cervix is required ✓ low risk of vasovagal reaction because the examination is painless. **2) Allergic reaction are infrequent** " There is an additional possibility of complications related to contrast agent intravasation. To minimize that risk, ✓ A diluted nonionic iodinated contrast agent with low osmolarity is used ✓ A gadolinium-based contrast agent may be used"

aftercare	➢ CM… Observe for reaction ➢ Renal dialysis if urgent CT with contrast in Patient e' renal insufficiency.			
CM	**IV:** IV contrast medium may or may not be needed, depending on the clinical indication **Non-Indicated:** ✓ Suspected tracheal stenosis ✓ Evaluation of stent patency **Indicated:** ✓ Evaluation of airway involvement by malignant disease. • Differentiate B from M. • Better staging of malignancy ✓ suspected cases of a vascular ring or sling, ✓ To guide trans bronchial biopsy, identifying the course of the mediastinal vessels 100–120 mL of nonionic CM at a rate of 3 mL/s through a peripheral angiocatheter is used. The scan timing can be tailored to highlight: ✓ **As** (25 sec. after inj.) ✓ **Vs** (40 sec. after inj.) **"In this setting, CT of the airway can be combined with CTA to show the relations between the vessels and the trachea"**	**Oral:** an oral contrast agent (e.g., water) is administered to opacify and distend the stomach and GIT **IV:** IV contrast agent is used (e.g,omnipaque 350) for complete evaluation.	Colorectal carcinoma	Diluted, non-ionic LOCM (in case of iodine allergy diluted Gd is used)

Patient preparation	**As usual**	**As usual+** "8hs. Fast" 1. **Bowel relaxing agents** e.g., buscopan (relax colon wall, decrease peristalsis)	**Bowel preparation** 2. **Low residue diet**… 48hs before exam 3. **Laxative** e.g. Pico lax …48hs before exam 4. **Bowel relaxing agents** e.g., buscopan (relax colon wall, decrease peristalsis) 5. **Fecal tagging** …**Tagitol** taken with breakfast, lunch and dinner day before (pt must add contrast agent to their diet to give stool different attenuation value than that of polyps .	**As HSG** • Scanning should be done on day7-10 of a regular menstrual cycle • No sex (48hs prior)

Technique	CT of the airways usually is performed with: 1) Inspiratory acquist. 2) Inspiratory and expiratory acquisitions in certain clinical applications, such as: tracheobroncho-malacia to detect airway narrowing and collapse 3) expiratory phase imaging, which can be valuable for detecting airway stent failure **Send Data to 3D workstation**	1. Stomach should be **adequately distended** by giving patient 6 g effervescent granules+ water "minimal" ✓ For detection of subtle gastric lesions ✓ avoid pitfalls "If the entire stomach is not well distended, disease may be obscured or, conversely, the collapsed gastric wall may mimic disease" **Check distention by scout**… if inadequate… another 3g is given. 1. CT was first performed with the patient in the prone position; IV contrast was not used 2. Before the patient was scanned in the supine position, gastric distention was again checked 3. Scanning with the patient in the supine position was performed after IV injection 4. Scanning began70 seconds after the initiation of the contrast injection, which corresponded to the portal venous phase 5. Scanning was performed from the diaphragmatic dome to the renal pedicle during a single breath-hold with the patient in the supine position **Send Data to 3D workstation**	1. Initially pt is transferred to CT table in left lateral decubitus. **A flexible rubber catheter is inserted into the rectum**(**40 puffs** "2-litres" of room-air, Co2 is insufflated via rectal tube into colon)… 2. The catheter is left in the rectum and a supine scout CT image is obtained to verify adequate bowel distention .. **If adequate, the CT examination is performed.** 3. The patient is then placed in the prone position. First unenhanced images are acquired with patient in prone position 4. Then CECT performed in portal-venous phase with patient in supine position **"Supine uninterrupted volume of data through abdomen – 32 second breath hold , Thin slices ~ 1-2.5 mm**" at 70 second delay between the start of CM administration and start of helical scanning 5. CT acquisition is performed from domes of diaphragm to lower margin of Symphysis pubis during a single breath hold **Send Data to 3D workstation**	1. The patient is positioned supine on the CT table in the lithotomy position. 2. Perineum is cleansed with povidone iodine solution 3. A disposable plastic speculum is used to dilate the vagina and obtain access to the uterine cervix, which is also cleansed with the povidone-iodine solution 4. A scout view of the pelvis is obtained with the speculum in place before contrast material is instilled 5. 10/12 fr. dedicated VHSG plastic cannula is positioned at external cx os (**no cx clamping** is applied) 6. **15 ml** iodine contrast dilution is instilled into uterine cavity using Automated power injector at flow rate 0.3 ml/s • 2.5ml water soluble iodine contrast • 12.5 ml saline solution. 7. Scanning is initiated 45 seconds after the contrast material instillation begins and is performed by using a 64-row MDCT scanner **Send Data to 3D workstation**

Image reconstruction & post-processing	**1. MPR** **2. MinIP** **3. VR**  **4. SSR** **5. Endoluminal imaging (fly-through) i.e. perspective volume rendering** ✓ Allows a user to look inside the lumen of a structure as if it were hollow and the user were inside of it. ✓ It can be applied to **air-containing structures** such as the colon, stomach, or trachea, or **structures with high density** inside such as enhanced blood vessels or a contrast-filled bladder	**Same**	**Same** ✓ **2D** Multiplanar reformatted saggital, coronal, oblique coronal and ✓ **3D** virtual colonoscopy (endoluminal) images are generated with fly through software  	**2D,3D evaluation is routinely performed during image interpretation** **1. Axial images…** 1st step in analysis is axial slices evaluation using intermedian soft tissue/bone window for assessment internal /external surface of female genital system <u>Various post processing algorithms may be used to reconstruct images for analysis…..The most useful algorithms are</u> **2. Multiplanar reformatting:** Bi-dimensional images displayed in sagittal, coronal, oblique views **NB:**(**Curved MPR**)used for unfolding uterus (allow assessment of the cervix, uterus, and fallopian tubes in a single continuous plane) **3. Maximum intensity projection (MIP)** This post processing method is used to obtain 3D black-and-white images of the cervix, uterus, and FT with excellent anatomic detail especially that difficultly visualized on 2D images. **However**, the method is not useful for detecting intrauterine lesions, which may be missed 

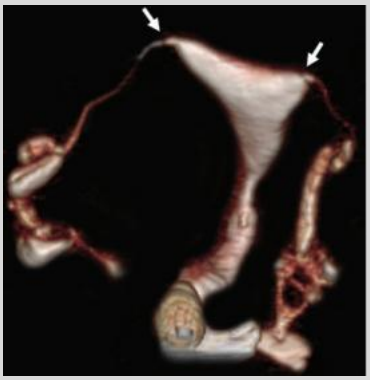


Endoluminal image shows trachea, carina and right upper lobe (RUL)

4. Volume rendering

This reconstruction algorithm provides 3D external views of the entire female reproductive system, allowing the detection of

- Stenoses,
- Wall irregularities,
- Polyps, and
- Hydrosalpinx



5. Virtual endoscopy

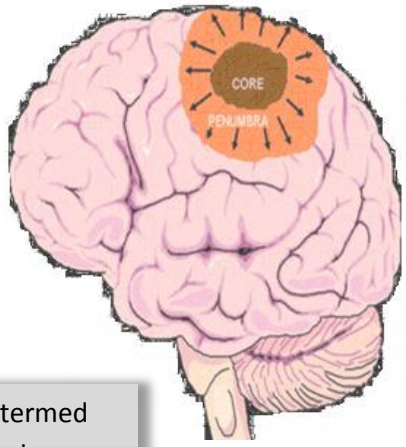
Create endoluminal image as hysteroscopy. Such information may enable verification of questionable findings on images obtained with other reconstruction methods

Allow accurate delineation of lesions located in CX canal, endometrial cavity, FT(when dilated)

SPECIAL SYSTEMATIC TECHNIQUES

1. Neuroimaging & Spine……CT perfusion:

- ***Basic principle:***



Perfusion refers to the passage of blood from an arterial supply to venous drainage through microcirculation which is necessary for the nutritional supply to the tissues and for clearance of unwanted products of metabolism.

Aim and Objective of CT Perfusion:

To assess the extent of salvageable tissue in acute stroke

"Salvageable tissue means that is decrease in the flow of blood to a particular area of brain, collateral supply from normal surrounding vessels try to compensate the blood flow to its periphery"

Concept of Penumbra: The central area does not receives this collateral circulation & is termed as infarct also called umbra while surrounding potentially less blood supply area is termed as penumbra

- ***Indication:***

1. Acute ischemic cerebral infarction.
2. Chronic stenosis of supra-aortic or intra-cranial arteries.
3. Currently evaluated indications include:
   - ✓ Vasospasm after SAH
   - ✓ Evaluation of cerebral neoplasms

- ***Contraindication:***
- ***Advantages:***
  - **Widely available**.
  - **Fast:** Perfusion CT can be performed quickly with any standard spiral CT scanner, and perfusion maps can be generated in a short time at workstation equipped with appropriate software
  - **Economical** and causes little discomfort to the patient
  - Easily providing **quantitative perfusion** metrics.
  - Both visual inspection and semi quantitative methods have potential roles in CT Perfusion analysis

- ***Disadvantages (limitation):***

1. **Limited coverage area**: - The main challenge of perfusion CT used to be limited coverage (2-4 cm/ scan), but newer 256 slice scanner can provide whole –brain coverage, and in the next few years this coverage will be widely available
2. **High radiation dose:** - Due to long scanning time, radiation dose is usually much higher than routine CT scan
3. **Motion artifact:** Motion artifact is the other limitation in many acute stroke patients, since sedation is frequently not possible, but immobilization of the patients head can control the movement
4. **Operator dependability:** - for qualitative as well as quantitative post processing, operator experience and clinical correlation is of prime importance for the correct analysis of CT Perfusion data

- **Contrast media:** To obtain functional information regarding cerebral blood flow, a small IV contrast is given and several slices acquired repeatedly at a fixed interval for instance 50 ml contrast administered at the rate of 5ml/sec for 45 sec in cine mode

  Contrast bolus
  - ✓ Short time 4-6 s so the bolus volume is limited
  - ✓ Rate 5-10 ml/sec, high iodine conc.

  Cycle time: 1 image /s is enough to trace bolus

- **Technique:** Sequential CT slices in cine mode during IV CM injection aiming at calculation of The following parameters:

1. CBF (Cerebral blood flow)..
   - Normal 50-80 ml/100 mg brain tissue / min
   - Irreversible infarction if < 10-15 more than 2-10 min
   - Between 10-25 , function cease but can be restored if reperfusion.

2. CBV (Cerebral blood volume).. is the volume of blood available per unit of brain tissue and is usually measured as milliliters per 100gm of blood
   - The % of intravascular volume in a given brain area
   - It increases in the penumbra (local VD)
   - But it decreases in the infarcted area (bad sign)

3. TTP(Time to peak)... refers to the time taken by the contrast to achieve maximum enhancement (HU value) in the selected region of interest (ROI) before its value starts decreasing

4. MTT (Mean transit time).. is the time between the arterial inflow and the venous outflow
   - TTP, MTT are Parameters used to recognize delayed perfusion (sensitive)
   - They are non-specific for infarction.

PARAMETERS FOR CTP 16 & 64 Slice CT

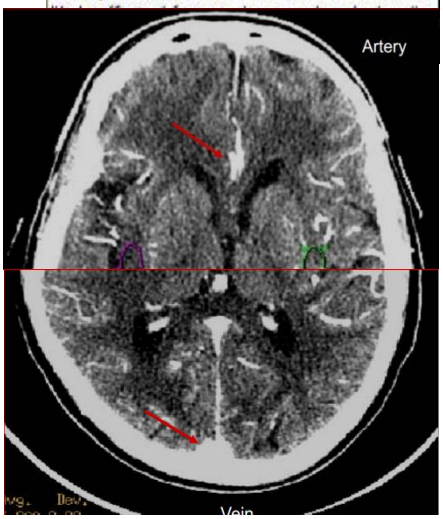
POINTS	16 slice (CT)	64 slice (CT)
Scan type	Cine mode	Helical mode 0.4 sec
Slice thickness	5 mm	5mm
Interval (mm)	0	10.00
Range	4 Contiguous 5mm sections	4 contiguous 5mm sections
KV	120	80
mA	200	200
Gantry angle	Parallel to orbital roof	S0.0
No. of images	200	336
Rescan delay	5s	5s
Contrast/ duration	50ML AT 5ml/sec 45 sec	50ML AT 5ml/sec 45 sec

Data Acquisition : Depending upon the type of scanner, one can take 1-4 sections of 5-10 mm thickness at the upcoming levels

Fig. 11.1. Perfusion studies in acute stroke are centered at the level of the basal ganglia to include portions of those vascular territories mos

- ✓ Present-day 16 slice CT do not allow for whole-brain perfusion assessment
  - Thus, if an **anterior circulation infarct** is suspected, data acquisition is done at the basal ganglia level and
  - If a **posterior circulation infarct** is likely, then at it is done at the level of the mid cerebellum
- ✓ But in 64 slice MDCT slice scanner can provide whole brain coverage

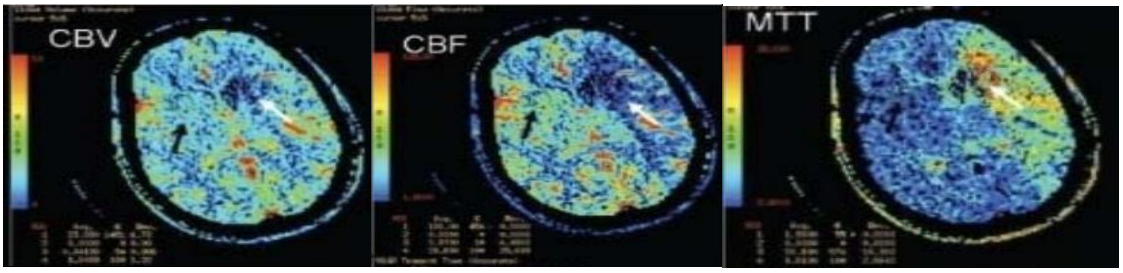
Post Processing of CT Perfusion Data ….With help of specialized software.



- ✓ For interpretation we have to define artery and vein, subsequently the perfusion MAPS generated by the software
- ✓ After the acquired data set is loaded on the computer, the software requires us to define the venous structure showing maximum enhancement which is typically set at the confluence of sinuses (Torcula herophili) as an ROI after the auto segmentation of the brain parenchyma has been done by the software
- ✓ It helps in the generation of color coded maps along with TAC (time attenuation curve), from which relative values of TTP, MTT, CBV and CBF can be calculated for any area of interest automatically.

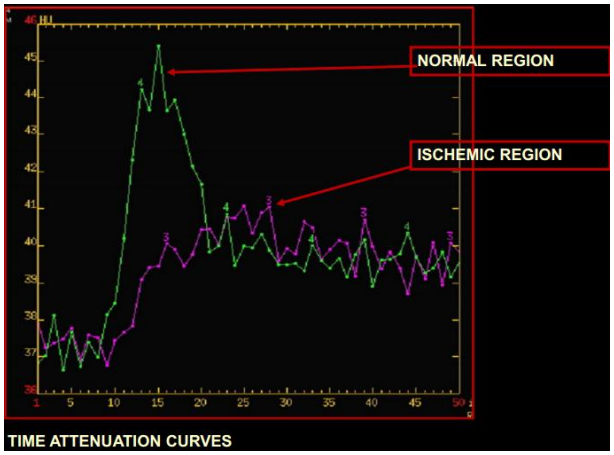
Data interpretation

- ✓ The various color coded maps are then generated representing the relative quantities of blood flow and transit time across the selected slices of the brain parenchyma
- ✓ Comparisons with the normal parenchyma can then be done by placing the ROIs in the areas to be analyzed

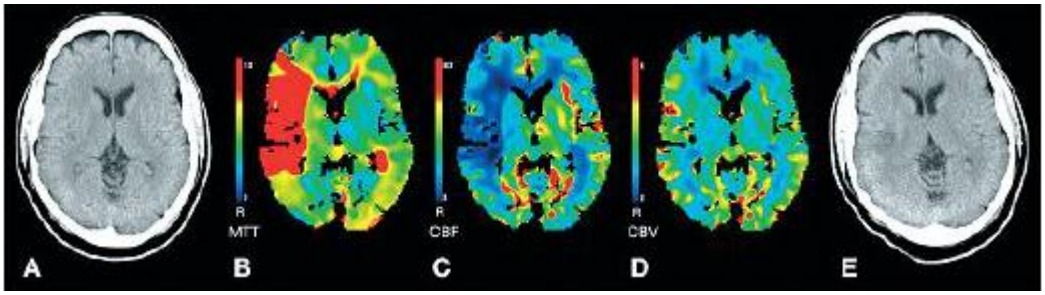


Color Coded Perfusion Maps

- *Normal finding & interpretation:……*Flow of Contrast in Infected Core

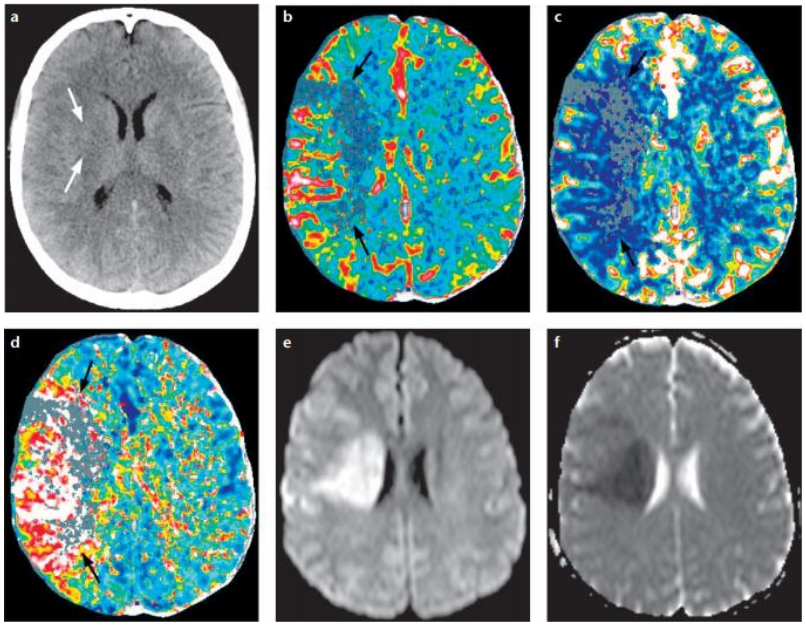


- ✓ Umbra region :
  - CBF & CBV the flow of contrast is reduced
  - MTT and TTP is raised
- ✓ Penumbra region :
  - CBF the flow is reduced
  - CBV may be raised/normal/reduced
  - MTT /TTP is raised



"Territorial infarction with penumbra and thrombolysis" 50 ys old patient suffering from acute left sided hemiparesis
Native initial CT scans **(a)**and PCT**(b-d)**were performed 2hs after the onset of symptoms -PCT scans were evaluated using a deconvolution algorithm-No early signs of infarction were identified on the initial CT study. On the MTT and CBF parameter maps **(b, c)**a large area of focal hypo perfusion can be identified, which includes 2/3 of the territory of the right MCA. Within the lesion no decrease in CBV is found**(d)**.Therefore the complete lesion was considered as tissue at risk, systemic thrombolysis was performed .Infarction as seen on the native follow-up CT scan **(e)**was confined to a rather small hypo dense lesion in the right external capsule

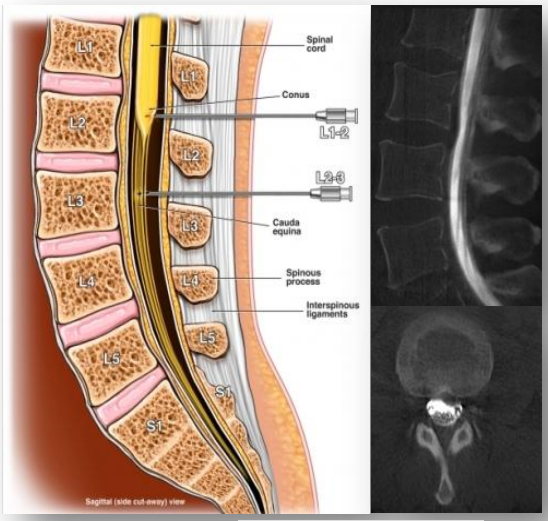
	CT perfusion	MR perfusion
Availability	CT scan is more widely available as compared to MRI and thus imaging can be done earlier	
Speed	Evaluation of the carotids, intra cerebral vessels, and cerebral perfusion can be done in a very short time: approximately 5 min	
Cost	It is relatively less expensive	
Sensitivity and specificity		MRI perfusion and diffusion imaging provide similar information with greater sensitivity and specificity "At present MRI perfusion has more evidence in its favor"
IR exposure	The major disadvantage of CT scan is the exposure to ionizing radiation.	
coverage	Unable to image the entire brain for perfusion imaging "present-day scanners"	



a-e A 30-year-old female with left hemiparesis
(a) Minimal hypo attenuation is observed on non-contrast axial brain CT image at the level of the right lentiform superior nucleus (arrows) .**6 hours after the onset of acute symptoms** Relative CBV **(b)**, relative CBF **(c)** and MTT **(d)** CT perfusion maps show large perfusion defect observed in the feeding area of the right MCA (arrows). Despite the wide perfusion defect observed on CT images, it was noted that tissue progressing to infarct has been arrested in the right corona radiata on diffusion weighted MR image **(e)**, and apparent diffusion coefficient (ADC) map **(f)**

2. CT Myelogram(not important)

• Technique



Lumbar Myelogram

- ✓ The CT myelogram procedure begins with a spinal tap performed on the lumbar region of the spine
- ✓ A contrasting dye injected into the spine
- ✓ The patient is placed on a rotating table during this time and strapped into place.
- ✓ The table will then rotate in such a way that the patient is upside down for a few minutes "This odd movement is really quite useful because it will allow the contrasting dye some time to get into and spread in the spine".
- ✓ Cuts are then taken and a blood patch is used to seal the wound to the spinal column.

✓ Technique tips& tricks

- Turning the patient a few times prior to CT ensures even distribution and reduces layering effects
- CT myelography should be delayed for up to 4 h to allow dilution of the contrast medium
  "A very high concentration may cause difficulty in resolving the cervical nerve roots"
  - In studying the spinal cord a delay is not required, though again good mixing of the CSF with contrast medium is essential
  - Delayed CTM is needed in suspected syringomyelia

• Indication

This imaging technique may be used for diagnosing various disorders of the spine It could be performed to check for herniated discs, spondylosis, and arthritis, among other problems

• Advantages over myelography

1. The superior contrast resolution of CT allows the definition of very dilute contrast medium, e.g. beyond a spinal block, thus avoiding the need for a cervical puncture.
2. Nerve root exit foramina may be studied by CTM in both the lumbar and cervical region, and has been shown to be a sensitive technique, though it fails to demonstrate far lateral discs.

• Complication

1. Nausea, headaches, and vomiting "The headaches are usually mild and transient"
2. Seizures "rare" This occurs once the dye enters into the spinal canal and leaks into the brain "keeping head slightly raised may prevent this".
3. Spinal fluid leaks out "epidural blood patch may **be** used **to** seal this leak"

3. HRCT(CHEST)

- ***Tech :***

  Thin collimation (1-1.5 mm) + High spatial resolution reconstruction algorithms

  - ✓ Large interspace gaps (2cm) … According to machine
  - ✓ Low dose (40 mAs) standard dose (160 mAs)

  - ✓ HRCT chest (supine and prone)
    - Asbestosis (diff initial lung fibrosis from gravitational effect)
  - ✓ HRCT chest (inspiration/expiration)
    - For small airway disease (air trapping)

- ***Indication***

  Diffuse lung disease

  - ✓ ILD(IPF)… FUP course of disease, effect of therapy.
  - ✓ Detect early morphological changes in patient with suspected early emphysematous asbestosis.

- ***Disadvantage***
  - Old machines: Suboptimal detection of LNs and small lung nodules
  - MDCT: with 64 slice, the entire lung with 1 mm collimation takes 10s.

Fig. 16.4. Small subpleural lung nodule (*arrow*). Visualization with 120 kV and 120 mAs

Fig. 16.5. Small subpleural lung nodule (*arrow*). Visualization with 120 kV and 20 mAs. Please note the higher noise rate with 20 mAs, but the diagnosis can be made nonetheless

Thin section CT!!!!..... Indicated in focal lung disease
(As HRCT but without high spatial frequency)

- CM: 2 amp urograffin mandatory + oral gastrograffin(if suspecting oes. path)

- Technique:
  - ✓ FOV: In bronchogenic CT.....Scans must be taken down till region of suprarenal gland(Mets)
  - ✓ Slice thickness, interval: for thymus…5mm(no lung window)

- Filming: 20 images… axial (Mediastinum, lung, +/-bone)

Cardiovascular system

Contrast medium application for MSCT: **Arterial and parenchymal enhancement**

Basic rules for arterial CM dynamics:

- **Enhancement directly proportionate to**
  - ✓ Injection flow rate (iodine flux)(mL/s) and iodine concentration (mg I/mL)
  - ✓ Injection durations (cumulative effect and recirculation)
- **Enhancement inversely related to**
  - ✓ Cardiac output
  - ✓ Central blood volume
  - ✓ Body weight

For liver (HA, PV)

- **CM media enter parenchyma and fill EC and IS spaces,**
  - ✓ So, enhance less than nearby arteries
  - ✓ And, peak much later than arterial enhancement
  - ✓ So, independent on rate only on amount of CM (600 mg I/kg)
- **For hyper vascular hepatic lesions**
  - ✓ Late arterial phase (10-15 s after contrast arrival to aorta)

Any CT exam with contrast

- Wide bore cannula
- Type of contrast
- Volume (from 60 to 150 mL)
- Iodine concentration (300-350-400 mg iodine/mL)
- Injection rate (3.5-5 mL/sec)
- Monophasic or biphasic
- Delay (test bolus or bolus tracking)

General CTA injection strategy……..Injection rate, duration, scan time, delay (according to machine)

1. Slow acquisitions (20s or longer)
   - 1.2-1.5 g I/s
   - Delay set to patient CMTT
   - biphasic or multiphasic injections may be needed
2. Fast acquisitions (10s)
   - Either increase iodine flux (conc. or rate) or
   - Increase injection duration and scan delay
3. Very fast acquisitions (5s or less)
   - The same… Avoid respiratory and cardiac motion artifacts

No need to use max machine capacity especially with mesenteric and LL CTA

4. CTA

Definition:

Relatively new non-invasive volumetric imaging technique ccc by:

1. Non-invasive injection of CM
2. Tracing of dye through BVs (ROI)by MDCT
3. Post-processing of images into 3D reconstruction modalities for easier, better interpretation.

Indication:

H&N	PULMONARY	THORACIC AORTA	ABD AORTA	LL	Renal mesenteric
1. Carotid body tumor 2. Stenosis 3. TIAs 4. AVM	1. Atypical chest pain 2. D-dimer evaluation 3. Unclear dyspnea 4. follow-up patients with known PE 5. Screening for high-risk patients with known DVT.	1. Aneurysm 2. Trauma 3. Significant Ath. Plaque 4. Intramural Hematoma 5. FUP of Stent Graft 6. Aortic Coarctation 7. Congenital Anomalies	Aneurysm To Detect: ✓ Site ✓ Extent ✓ Brs ✓ Its Relation to renal Artery For Surgical Planning	1 Aneurysm 2 Trauma 3 Limb ischemia 5. FUP of bypass graft 6. Pre-op assessment to detect inflow, run-off of vs. for surgery 6 AVM	1. Renal A. aneurysm 2. IBD assessment 3. Ischemia(mesenteric) 4. Transplant (renal donor evaluation) 5. Tumor staging, surgical planning 6. Renovasc. HTN disorders 7. Renal vasc. anomalies + congenital malformation

Contraindication:

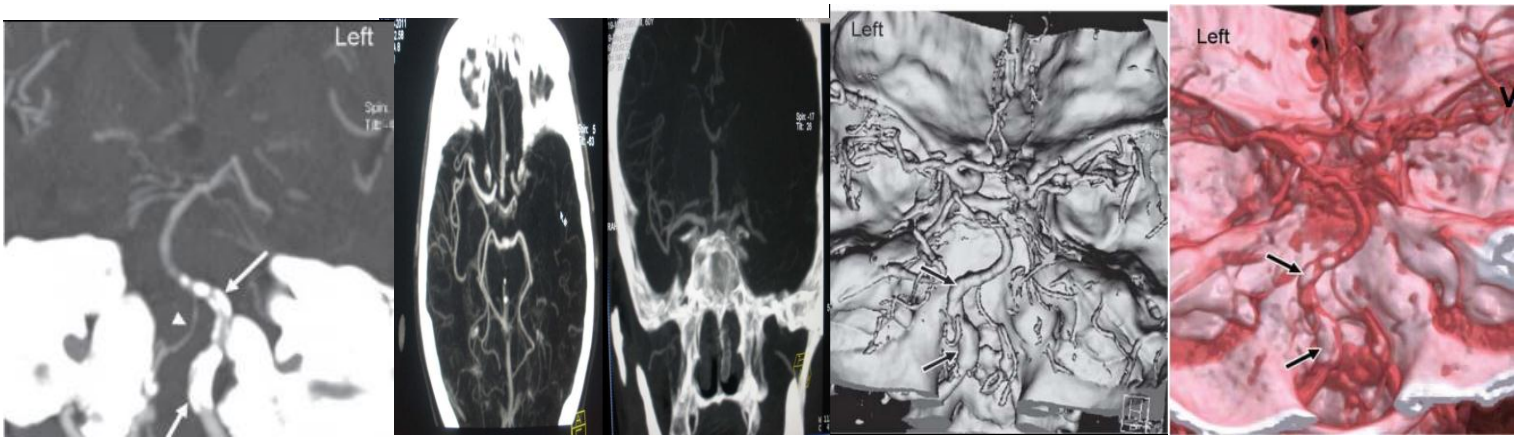
- **IR:**
- **CM:**
- **TECN:** for BB
  - ✓ severe uncontrolled arrhythmia,
  - ✓ HB, advanced degree of HF,
  - ✓ very high HR not responding to BB, anxiolytic

Advantages & Disadvantages:

- Non-Invasive
- Low dose of CM + better conc.
- High spatial resolution
- Cost effective
- It has ability to distinguish *vessel occlusion from near total stenosis*
- Able to detect plague morphology with calcified *plague* easily distinguished from soft or lipid laden plaque
- *Comparison to MRI* as it is less time consuming with significant no flow related artifacts encountered
- It is largely replacing *DSA* for diagnostic purpose

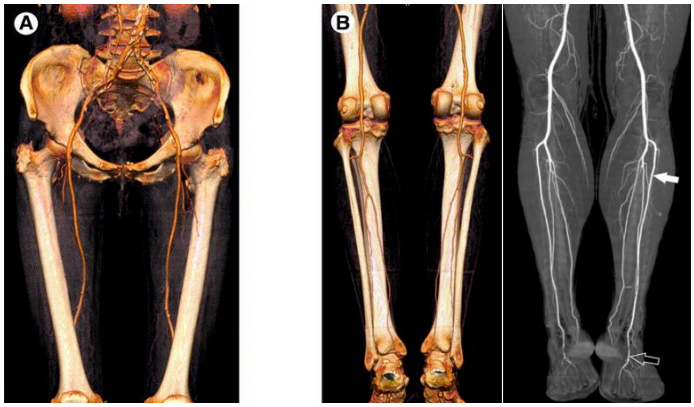
limitation:

- *Ionization Radiation*
- *Contrast* is needed
- Reconstruction of CTA data is *operator dependent* so there may be inherent loss of information in this technique
- Significant *time n*eeded for post processing of source images at a workstation
- Difficult to scan from the aortic arch to the intracranial circulation at appropriate slice thickness in one setting.(*coverage?*)

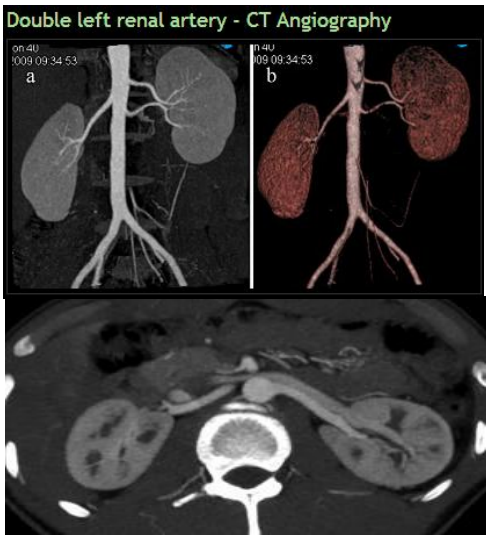


H&N…. MIP, SSR, VR

Pulmonary Thoracic aorta

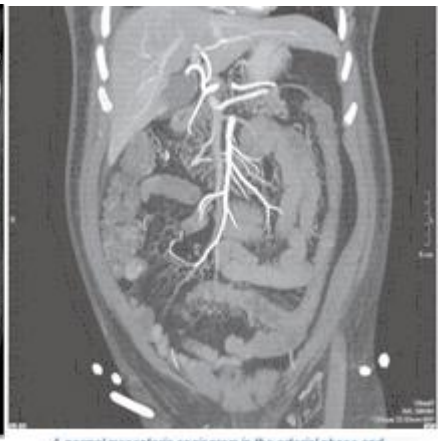


Lower limb CT angio



Renal CT angio

Thick slab MIP (maximum intensity projection) of mesenteric vasculature within the abdomen.



A normal mesenteric angiogram in the arterial phase and coronal plane. Visualisation of smaller vessels is aided by slightly thick MIP images.

Mesenteric CT angio

Patient preparation:

As usual

Contrast media:

- To deliver an appropriate amount of iodine, injection rates of 4 –5 mL/sec and highly concentrated contrast medium (iodine, 350 –370 mmol/mL) are preferable
  - ✓ LOCM…(conc. ,amount, injection rate according to study).
  - ✓ LOCM 370 (300 In LL/HEAD,NECK???)…100-150ml (4-5 cc/sec).
- Flushing of the veins reduces streak artifacts due to beam hardening, especially at the thoracic inlet

Technique:

After pt preparation& IV cannula insertion (precontrast round is taken in thoracic aorta/renal mesenteric angio)

- **Pt position**
  - ✓ Supine
  - ✓ Head 1st (except LL)
- **Scout…** AP(lateral in H&N)

PARAMETER	NECK	BRAIN
Range	Arch of Aorta to BOS	BOS to Vertex
Scan	Helical	helical
Slice thickness	2.5 mm	1.25 mm
Interval	1.25 mm	0.63 mm
Speed	7.5 mm	3.75mm
Pitch	1:5:1	0:75:1
kv	120	120
mA	280-300	290-300
Rotation time	0.6	0.6 sec
Fov	35 cm	25 cm

Set device on ROI, set parameters(as conventional CT)

- **Localizer(post-scout)**
- **Field of view**
- **Slice thickness & interval**
- **Exposure factors: KV, mA.**

Dye is injected better by pump to fix rate of injection

- **CM transit time :**
  - ✓ Time interval from IV bolus injection of CM to appear in the arterial territory of interest.
  - ✓ For CTA studies, scanning delay = patient CMTT
    With faster scan times and shorter injection durations, we may add a diagnostic delay (for e.g.: CMTT +8 sec).

- **Scan time, delay…**
  - ✓ After delay time (differs according to study)… CT device take images as dye pass through ROI
  - ✓ Adjust (time of scanning of ROI/Time of dye passage at study)by:
    - ➢ *Automatic Bolus tracking (Smart Prep, and Sure Start) by ROI*……
      - ***Advantage:……***These techniques are fast, more accurate and easy to use and require only a single contrast material injection "No separate test bolus".
      - ***Disadvantage:……***
        - ✖ Increase scan delay
        - ✖ that a large target vessel for monitoring the CM arrival is required, and
        - ✖ an additional delay for table movement and patient instruction is necessary

Double barrel injectors & saline flushing

- Two syringes
  - ✓ Saline
    - Flush after CM injection to improve CM utilization
    - Test injection pre
  - ✓ CM

Attention……..*Breath hold without valsalva*
Valsalva >>> increase intrathoracic pressure >>> affect VR and so CM which is coming from UL veins usually

- *Test bolus injection* is the alternative to assess the individual circulation time.
  - ***Its major advantage*** is that it provides information about the timing of both arterial and venous enhancement in the vessels of interest. "The individual start delay can be optimized by placing the scan between the arterial peak and venous contrast material upslope".
  - Table movement and patient instructions can be performed prior to the optimal image acquisition window.
  - ***The disadvantage*** is the necessity for an additional injection of about 10 mL of contrast agent (10%–20% increase of total amount)" .

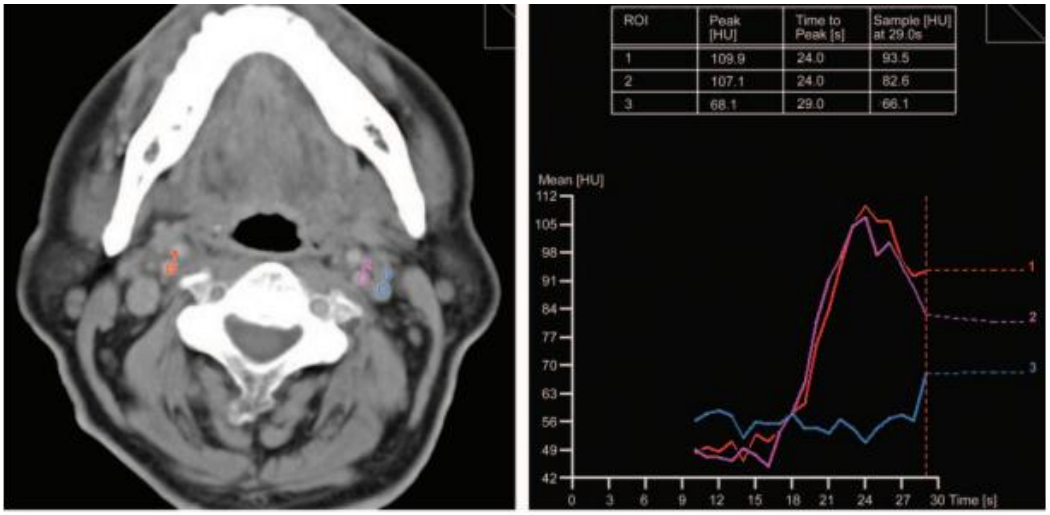


Figure 1. Test bolus method. **(a)** Axial image shows the right internal carotid artery (ICA) *(1)*, left ICA *(2)*, and left internal jugular vein *(3)*. **(b)** Diagram shows the enhancement curves for the right ICA *(1)*, left ICA *(2)*, and left internal jugular vein *(3)* after injection of 10 mL of contrast material and a saline solution bolus. The individual start delay can be set between the arterial peak and the venous upslope. *ROI* = region of interest.

- *Fixed time delay specific for each study.*

Filming & post-processing:

Image Reconstruction

- To reduce image noise, images may be reconstructed slightly thicker than the detector collimation, for example with a 0.75-mm section thickness from a data set acquired with 64 x 0.6-mm detector collimation .
  - "Overlapping image reconstruction should always be performed to improve 3D post processing"

Image Post processing Techniques

- Several image processing techniques are currently being used clinically . Image processing involves:
  1. **Multiplanar reformation (MPR) and**
  2. **Maximum intensity projection (MIP), as well as**
  3. **Surface and Volume rendering**

- Because bone and calcifications are seen as a particular problem in CT angiography, a variety of different approaches have been advocated to cope with this problem:

  - ✓ Editing, volume cropping, manipulation with transfer functions, and segmentation are common but time-consuming techniques, not convenient in the emergency setting .
  - ✓ Visualization with **interactive MPR**, **sliding thin-slab MIP**, or **standardized volume rendering presets** in combination with clip planes is more appropriate.

1. MPR:

Bi-dimensional images displayed in sagittal, coronal, oblique views i.e. only 2D views can be generated
Therefore, MPR should be combined with another visualization technique (thin-slab MIP or volume rendering) to display the vessel course.

- **Curved MPR:** A variant of MPR .
  - It provides a 2D image that is created by sampling CT volume data along a predefined curved plane.
  - This technique is employed to display tortuous structures; however, It is usually highly error prone and often inappropriate for exact measurements.

2. MIP

- MIP images are created by displaying only **the highest attenuation value** from the data encountered.
- The depth information along the projection ray is lost; to visualize the spatial relationship of various structures, the volume has to be **rotated** and viewed from different angles.

- **If bone or calcifications** are within the projection ray, these structures are represented on the MIP image instead of the contrast-enhanced vessel because of higher attenuation values. Therefore,
  - ✓ **Bone elimination techniques** are essential for processing vascular MIP images

  - ✓ **Thin-slab MIP images** viewed interactively may be an alternative.

"MIP is not suitable for the evaluation of stenosis in cases of dense calcification or stents, but thin-slab MIP can provide an excellent "road map" of the vessel course for further evaluation with MPR"

  - ✓ Superimposition of vessels leads to artificially altered lumen margins, and pathologic conditions may be hidden. To cope with this problem, a modification of MIP called **closest vessel projection** has been proposed

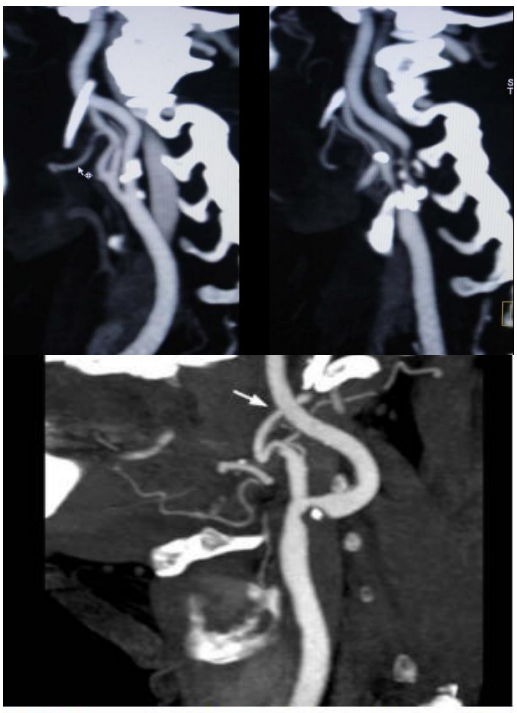
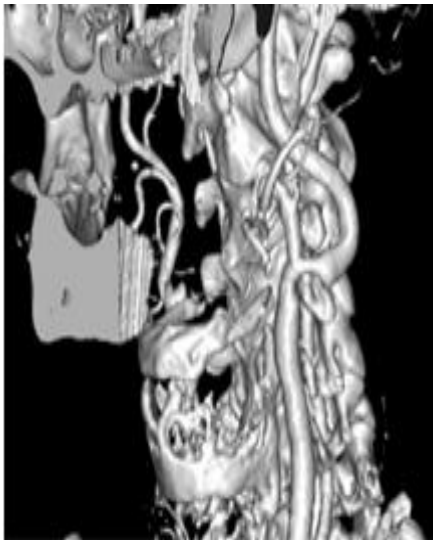


Figure 3. Thin-slab MIP image (slab thickness = 15 mm) shows the cervical part of the carotid artery. Superimposition of vessels or calcified structures alter lumen visualization (arrow).

3. SSR:



Shaded surface display image shows bone and contrast-enhanced vessels as well as calcified plaque. All voxels above the threshold are represented equally. Parts of the jaw were manually removed from the image to exempt the left ICA. The right carotid artery is partly visualized; an occlusion of the right ICA is evident.

Shaded surface display, or surface rendering, is an algorithm that provides a good 3D impression of the surface of an object

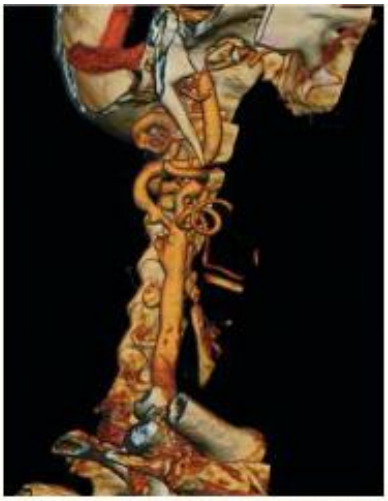
1. In the first step, the surface of an object is separated from other structures. "This is usually done by Thresholding"
   (Selecting a lower threshold of 200 HU will create a binary data set out of voxels with attenuation values above 200 HU

2. In the final image, the surfaces of structures meeting this condition will be represented, in CT angiography vessels and bone) As with MIP, bone elimination techniques have to be applied to extract the vascular structures

3. In the second step, a gray-scale shading procedure is performed to create light intensity in a given 3D scene, simulating surface reflections and shadowing from an artificial light to enhance depth perception

"Volume rendering has supplanted shaded surface display in virtually all CT angiography indications"

4. 3D volume rendering.



Volume rendering technique (VRT) demonstrate a higher grade, complex stenosis of the internal carotid artery in a patient with an acute neurovascular event

Volume rendering is a visualization technique that creates a 3D impression and provides densitometric information.

1. In volume rendering, all acquired data may be used; therefore, it requires *greater processing power* than MPR, MIP, or SSR
2. Visualization of CT angiography data with volume rendering is based on transfer functions that *map measured intensities to colors and opacities*.
3. Opacity values on a spectrum from 0% to 100% (total transparency to total opacity) are assigned along artificial rays that pass through the data.
4. Separation of different tissue types (i.e., bone, contrast-enhanced vessels, soft tissue) can be performed by applying multiple trapezoids, which can be color encoded.
5. Color can be applied to enhance the discrimination between structures

Normal finding + WW,WL:

Complication:

- IR
- CM...+Arterial necrosis

Aftercare:

- Observe For Reaction
- Anti-Histaminic In Case Of Need
- Monitor Patient For 30-60min, Discharge If Responsible Adult.

Previous exam: Anatomy of the coronary arterial tree and technique of multislice CTA

In general there are two main coronary arteries, that originate from the beginning (root) of the aorta, immediately above the aortic valve

1. **The left coronary artery** originates from the left aortic sinus, The LCA travels between the right ventricle outflow tract anteriorly and the left atrium posteriorly and divides into:

   A. Left anterior descending artery(LAD).....
      - The LAD travels in the anterior interventricular groove and continues up to the apex of the heart
      - The LAD supplies the anterior part of the septum with septal branches and the anterior wall of the left ventricle with diagonal branches
      - The LAD supplies most of the left ventricle and also the AV-bundle
      - The diagonal branches come off the LAD and run laterally to supply the antero-lateral wall of the left ventricle.

   B. The circumflex artery (Cx).....
      - The Cx lies in the left AV groove between the left atrium and left ventricle and supplies the vessels of the lateral wall of the left ventricle
      - These vessels are known as obtuse marginals, because they supply the lateral margin of the left ventricle and branch off with an obtuse angle

2. **The right coronary artery** originates from the right aortic sinus . The right coronary artery arises from the anterior sinus of Valsalva and courses through the right atrioventricular (AV) groove between the right atrium and right ventricle to the inferior part of the septum
   A. The first branch of the RCA is the small conus branch that supplies the right ventricle outflow tract
   B. Other branches include a branch to the SA node, some diagonal branches that supply the anterior wall of the right ventricle
   C. The large acute marginal branch (AM) comes off with an acute angle and runs along the margin of the right ventricle above the diaphragm
   D. The RCA continues in the AV groove posteriorly and gives off a branch to the AV node
   E. The posterior descending artery (PDA) is a branch of the RCA and supplies the inferior wall of the left ventricle and inferior part of the septum

Multi-slice Coronary CTA
Value:-
64-slice coronary CT angiography is highly accurate for the exclusion of significant coronary artery stenosis (>50% luminal narrowing) with negative predictive values of 97%–100%, in comparison with invasive selective coronary angiography

Indications
1 Exclusion of coronary artery disease in the low to intermediate risk patient
2 Evaluation for cardiac/pericardial anatomic abnormalities including masses, thrombus, etc.
3 Triple rule out study for chest pain and can evaluate for other causes of chest pain
4 Detect anomalies including myocardial bridging

Patient preparation:-
Image quality improved at low heart rates (<65 beats per minute)
1 Inspirational breath hold (-6beats/min)
2 Beta-blocker (50-100mg oral or 5–20 mg IV metoprolol)
3 Combination (-11beats/min)
4 Short-acting nitroglycerin- dilates coronary vessels for better visualization
5 Sedation if irritable
Patient postion-supine
Scannogram -PA from aortic arch to diaphragm
- 80 ml IV LOCM 370 at a rate of 5 ml/sec with a delay 7-9 seconds
- Entire cardiac volume scan with single breath hold (8-9 sec)
- ECG gating - scan at diastole when there is least heart motion
- Spatial resolution- 0.4mm
- Temporal resolution- 120 msec

Multiplanar reformatted (MPR) images for the confirmation of pathologic findings in the long and short axes of the vessel
Sliding thin-slab MIP (STS-MIP) images enhance the visualization of coronary artery stenosis in a long-axis view of the vessel if narrowing is caused by non-calcified atherosclerotic plaque

5. Cardiac CT

Contrast enhanced visualization of coronary As & myocardium using MDCT (16-64)

Indication:

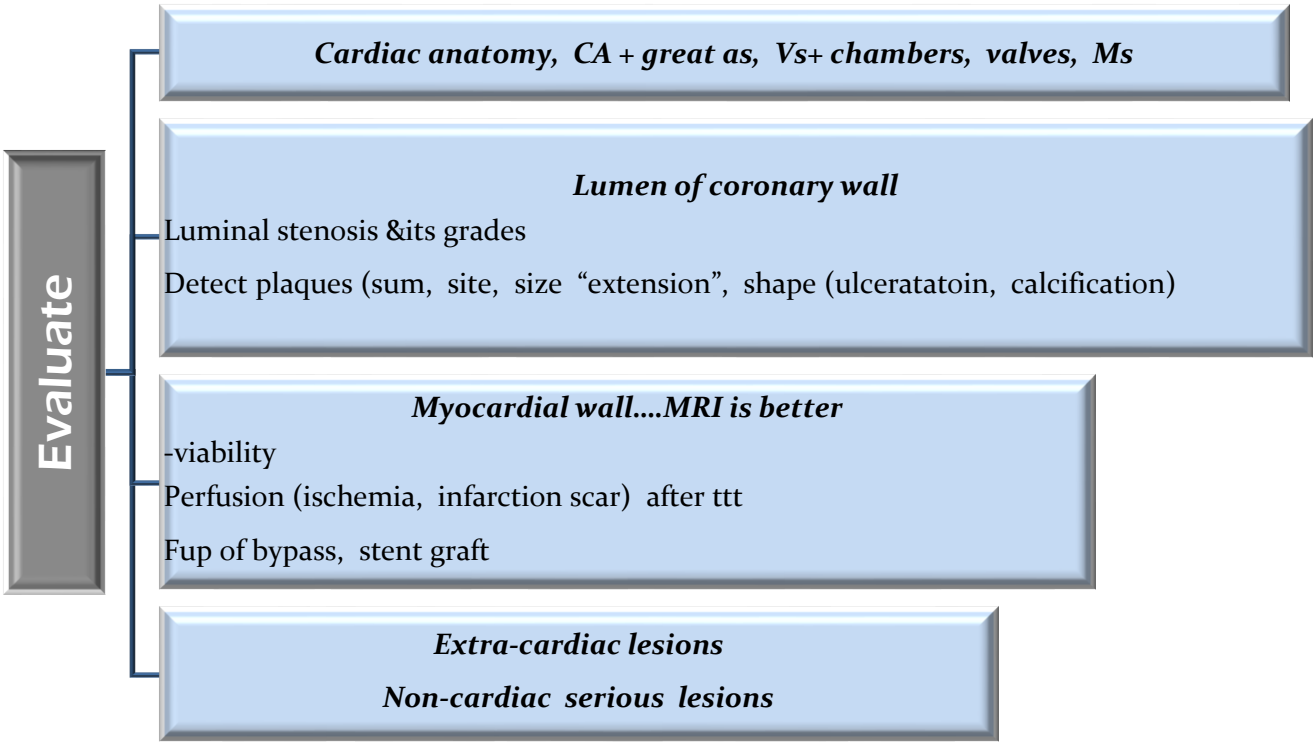
1. CAD……(suspected-known case of CAD)
2. Chest pain…
   - ✓ Screening for asymptomatic HRP > 2 risk factors…ca+2 scoring
   - ✓ Atypical chest pain
3. CA graft (post CABG to assess graft)
4. Before CA intervention to exclude anomalies.
5. Conv. angio alternative in case of contraindication.
6. As a triage in emergency room (especially in presence of non-elevated troponin and non-significant ECG)
7. Imaging& evaluation of cardiac performance
8. Non-cardiac serious lesion affecting Ht.

Contraindication:

- **IR:……**
- **CM:…..**
- **TECN:**
  - Patient with typical angina
  - for BB
    - ✓ severe uncontrolled arrhythmia,
    - ✓ HB, advanced degree of HF,
    - ✓ very high HR not responding to BB, anxiolytic

Advantages

- non-stressful
- cardiac cycle gated


Evaluate
Cardiac anatomy, CA + great as, Vs+ chambers, valves, Ms
Lumen of coronary wall
Luminal stenosis &its grades
Detect plaques (sum, site, size "extension", shape (ulceratatoin, calcification)
Myocardial wall….MRI is better
-viability
Perfusion (ischemia, infarction scar) after ttt
Fup of bypass, stent graft
Extra-cardiac lesions
Non-cardiac serious lesions

Disadvantages:

- Contrast
- Radiation dose

Prerequisites to overcome challenges:

- Moving heart, breathing artifact… so **MDCT(16/64)** with high speed, spatial resolution is used
- Arrhythmia…. **decrease heart rate..65 BPM**, decrease breathing
- Small diameter of CA lumen

Patient preparation: As usual+

- ECG monitoring e' QRS complex "clear regular"
- BB(oral, iv)for optimum regular HR (50-65 beat/min)
- Stop caffeine, Viagra
- Fasting 4 hs.

Contrast media: 400mg/ml (100ml)… 4-5ml/sec

Technique:

1. **Decrease heart rate**…….5-20 mg BB unless asthmatic patient, use verampil
2. **Scout film is taken with** FOV(1-2cm) sub carina to sub(below)diaphragm …unless there is internal thoracic graft start from subclavian artery downwards.
3. **Breath hold** for 15-20 sec……ca^{+2} scoring

4. **Contrast injection**
   - Inject 15 ml at first to determine CMTT
   - 60-100 ml are injected followed by 40ml saline at a rate of 4-5 ml/sec

5. **Data acquisition & ECG gating**

   ECG gating
   - Prospective…less time, radiation, yet contraindicated in arrhythmia
   - Retrospective….volumetric images, applicable in arrhythmia

   Data acquisition……Helical mode
   - Start 10 sec after injection
   - Axial at aortic level (10ml collimation at 2 sec interval.
   - Optimal quality is seen at diastole (65% of R-R cycle?)….RCA is better seen at 30%
   - Dual source CT……..
   - Extended CT protocol (increase FOV)to see coronary, PA
6. **post-processing & image reconstruction:**
   - MPR…
   - Curved MPR…..see lumen from ostia till distal end
   - MIP….
     - ✓ detect longer lengths of coronary lumen
     - ✓ more accurate for detection of significant CA lesions
   - VR….useful in CA anomalies…pre-surgical planning

Complication:

- IR
- CM…+Arterial necrosis
- BB: asthma, significant decrease HR, HF, Shock

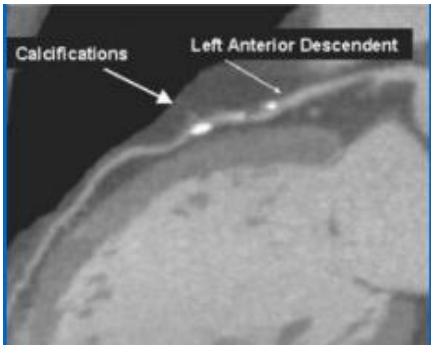
Aftercare:

- Observe For Reaction
- Anti-Histaminic In Case Of Need
- Monitor Pt. For 30-60min Discharge If Responsible Adult

1. Calcium screening (scoring).....For Calcified plaques

Indications

- Suspected CAD
- Atypical chest pain (DD)
- Risk stratification in aS/O pt with intermediate to high risk for future myocardial event



Patient preparation

- No special prep
- Oral BB if HR>70bpm, if rotation time >370ms

Technique

- Patient position
  Supine, arm elevated, ECG leads attached, heart in isocenter of the gantry
- Scan range
  - 1cm below carina to diaphragm (include entire heart)
  - Include lung !?
- Scan window
  - Start at 60% of the RR interval (usually least mobile point for the heart)

Fig. 20.1. Scan range for calcium scanning. The scan volume should include the entire heart from the mid level of the pulmonary artery (approx. 1 cm below the tracheal bifurcation) down to the diaphragm

- **Ca^{+2} scoring, sequential scan tech**
- **Ca^{+2} scoring, spiral scan tech**

Interpretation

Coronary calcium is a surrogate marker for the presence and amount of coronary atherosclerotic plaque.
MDCT permit accurate detection and quantification of coronary artery calcium

The so-called **'Agatston Score'**, which takes into account the area and the CT density of calcified lesions, is most frequently used to quantify the amount of coronary calcium in CT

Agatston score	Atherosclerotic plaque burden	Probability of significant CAD	Implications for cardiovascular risk	Recommendations
0	No plaque	Very unlikely, <5%	Very low	Reassure patient. Discuss general guidelines for primary prevention of CV diseases.
1–10	Minimal	Very unlikely, <10%	Low	Discuss general guidelines for primary prevention of CV diseases.
11–100	Mild	Mild or minimal coronary stenoses likely	Moderate	Counsel about risk factor modification, strict adherence with primary prevention goals. Daily
101–400	Moderate	Nonobstructive CAD highly likely, obstructive disease possible	Moderately high	Institute risk factor modification and secondary prevention goals. Consider exercise testing. Daily ASA.
>400	Extensive	High likelihood (>90%) of at least one significant coronary stenosis	High	Institute very aggressive risk factor modification. Consider exercise or pharmacologic nuclear stress testing. Daily ASA.

Agatston Score:

Measure Ca+2 burden of plaques….measure plaque density with attenuation value > 130HU

- Ca+2 load α athermatous plaque within CA
- Ca+2 = reliable sign of CAD (diagnosis)
- Increase ca+2….increase risk of stratification (prognosis)
- Monitor therapy if patient is already on statin…(FUP)

Ca+2 CA doesn't mean it's stenotic.
Ca+2 absence doesn't exclude CAD.

2. Coronary CT angiography

Indications

- Coronary artery anatomy
- Stenosis
- Stent viability
- graft anatomy and patency

Contraindication

- As usual
- Patient with known Diffuse multivessel disease
- Patient with known severe coronary Calcium

Patient prep

- General
- Fasting 4-6 hrs.
- ECG monitoring e' QRS complex clear regular
- Check current HR…….If > 65 bpm ,BB (50-100 mg metoprolol) is given 30-60 min prior to scan (no BB if #)
- 20 or 18 G IV access antecubital

Tech

- Position
  - Supine, arms elevated, ECG leads placed
  - Oral 0.8mg nitroglycerin immediately before scan (coronary dilatation)
- Scannogram
  - Entire chest/base of heart to carina
  - Patent IV access, hold breath 5s prior to scan
- Scan
  - Ca scoring 1st.
  - No Ca limits established for > 16 slice machine otherwise it is 335 Agatston score for 4S scanner and 1000 for 16S scanners
  - Contrast injection as mentioned
- Post processing
  - Curved MPR
  - Double oblique MIP
  - 3D volume rendering

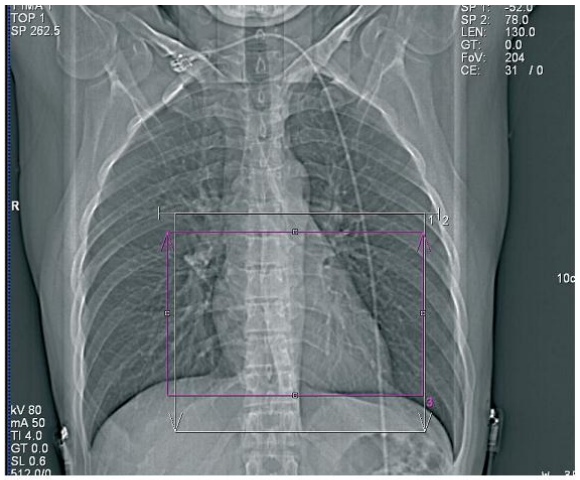


Fig. 21.1. Topogram. Arms above the head. The calcium scoring scan prior to the scan can be used as an additional localizer for the contrast-enhanced spiral, which is usually smaller than the nonenhanced scan. The carina is the upper border, while the base of the heart is the lower border

Fig. 21.3. 3D volume-rendered image. Can be used for global orientation and presentation of diagnosis (normal finding). These images should not be used for reading

Curved MPR of a right coronary artery, no stenosis present. This postprocessing type can be used for demonstration of diagnosis for a single coronary artery. Can also be used for cautious reading, note that motion artifacts (*arrow*) may look like a coronary stenosis

Non-calcified plaque

There is growing interest concerning the ability of contrast enhanced CT coronary angiography to detect (and possibly to quantify and to further characterize) non-calcified coronary atherosclerotic plaque

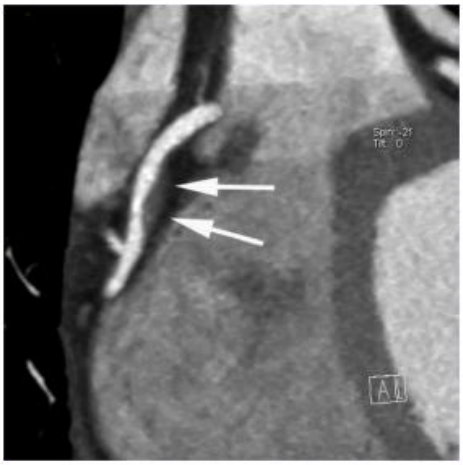


Figure 6 Imaging of coronary atherosclerotic plaque by multi-detector row computed tomography. The contrast-enhanced multi-detector row computed tomography data set shows a non-calcified plaque in the proximal right coronary artery with substantial positive remodelling and only a mild associated reduction of the coronary lumen.

Detection of coronary artery stenosis

1. *With the introduction of 16- and 64-sliceMDCT systems*, improved temporal and spatial resolution as well as substantially shorter scan times led to improved image quality throughout the entire coronary tree.

   Image quality may be degraded in
   - patients with severe CAD due to the presence of extensive calcifications which potentially limit precise assessment of the stenosis severity.
   - patients with higher heart rates or arrhythmias.

2. Improvements can be expected from the introduction of *dual-source CT systems*, which provide higher temporal resolution permitting visualization of 98% of all coronary segments without motion artifacts, even without lowering the heart rate by administration of beta blockers .
   Moreover, even in patients without stable sinus rhythm, a high accuracy could be obtained

3. In addition, *256-slice MDCT systems*, whose large coverage along the z-axis (patient's longitudinal axis) may allow imaging of the entire heart in a single cardiac cycle and will make coronary CT angiography less susceptible to arrhythmias or heart rate variability, will become available in the near future

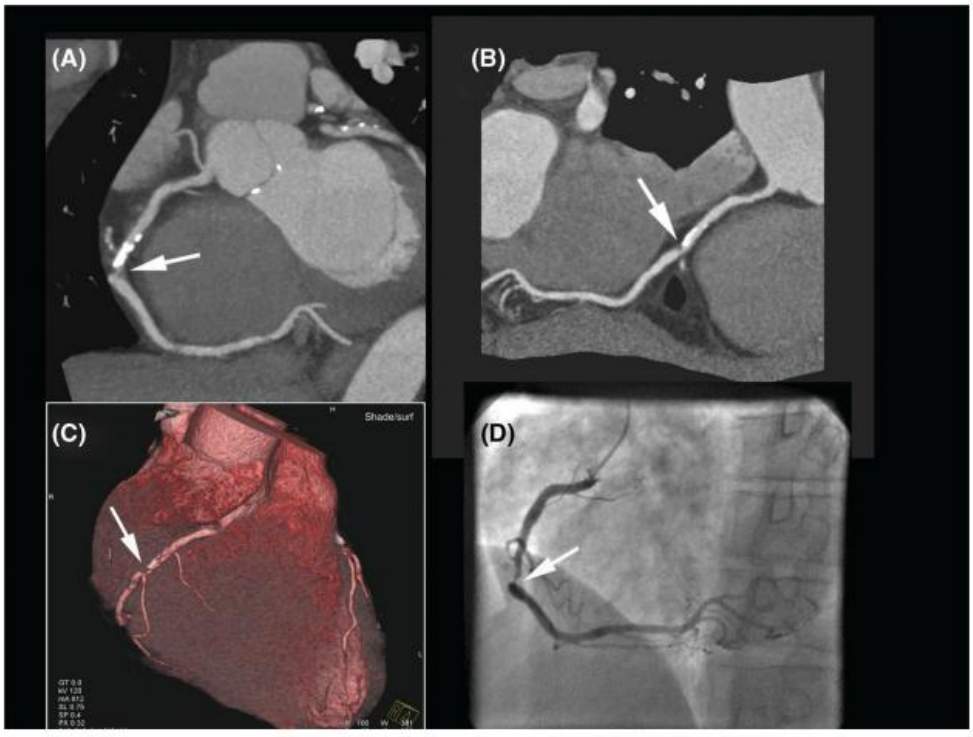


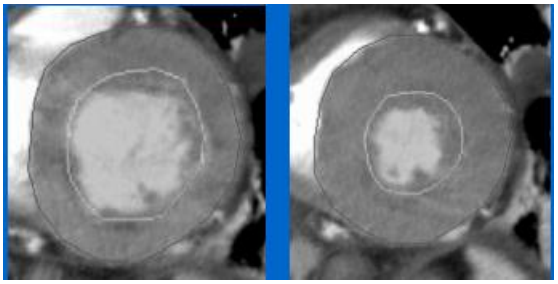
Figure 1 Coronary artery stenosis detection with multi-detector row computed tomography. High-grade stenosis of the mid-right coronary artery in a 55-year-old man with atypical chest pain. (*A*) A maximum intensity projection, with a high-grade luminal reduction distal to a calcified segment. (*B*) A curved multiplanar reconstruction. (*C*) A three-dimensional rendering of the heart and right coronary artery. (*D*) shows the corresponding coronary angiogram.

3. Functional cardiac imaging "Non-coronary imaging"

Technique

Same as coronary

- No need for Ca scoring



After data acquisition (retrospective)

- For LV function (quantitative functional parameters)
  - Reconstruct complete data sets at end systole & end diastole
  - Parameters auto computed (EF, EDV, ESV)
- For wall motion analysis (semi quantitative)
  - 20-25 cycles in the R-R interval are reconstructed in the short axis, two, three and four chamber views
  - Cine mode is used to assess (normo, hypo, A, dyskinesia)

A. Left and right ventricular function

On workstation, functional parameters such as

- left and right ventricular end-diastolic and end-systolic volumes,
- stroke volume,
- ejection fraction, and
- myocardial mass can be calculated from cardiac CT angiography data sets

Various studies have shown that for these ventricular functional parameters, MDCT correlated well with magnetic resonance imaging, echocardiography, or gated SPECT

However, Other diagnostic tests without radiation exposure or the need for contrast injection (i.e. echocardiography) are the methods of choice

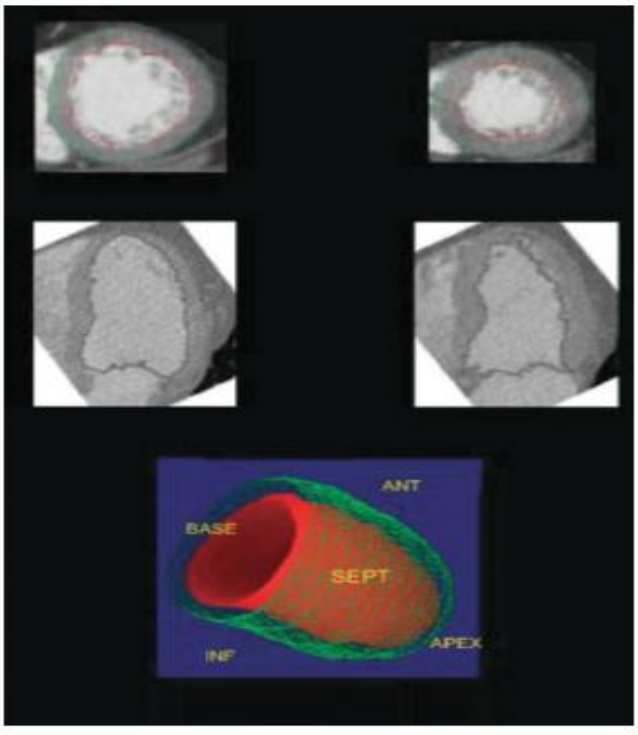
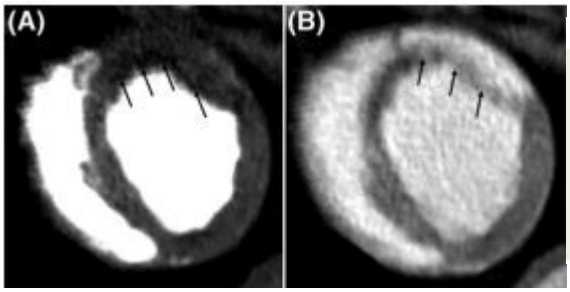


Figure 7 Assessment of left ventricular function and volumes by multi-detector row computed tomography. By tracing endocardial contours of standardized reformats in end-systolic and end-diastolic short- and long-axis views, left ventricular volumes and left ventricular ejection fraction can be derived from multi-detector row computed tomography data sets.

B. *Myocardial viability and perfusion*

- MDCT allows assessment of myocardial viability by studying 'late hyper-enhancement' in a similar fashion as magnetic resonance imaging.
- In the setting of acute, sub-acute, and chronic myocardial infarction, myocardial perfusion defects can be observed during the early phase of the contrast bolus ('early defect')
- Subsequently, 5–15 min following contrast infusion, late hyper enhancement of infarcts becomes apparent
- Although these results appear promising, magnetic resonance remains the non-invasive gold standard to assess the size of myocardial scars.

- Furthermore contrast-enhanced MDCT can provide assessment of myocardial perfusion .
- MDCT may be capable of detecting early perfusion defects in myocardial territories supplied by vessels with obstructive atherosclerosis. The high spatial resolution of MDCT also allows for the assessment of the subendocardial distribution of myocardial ischemia



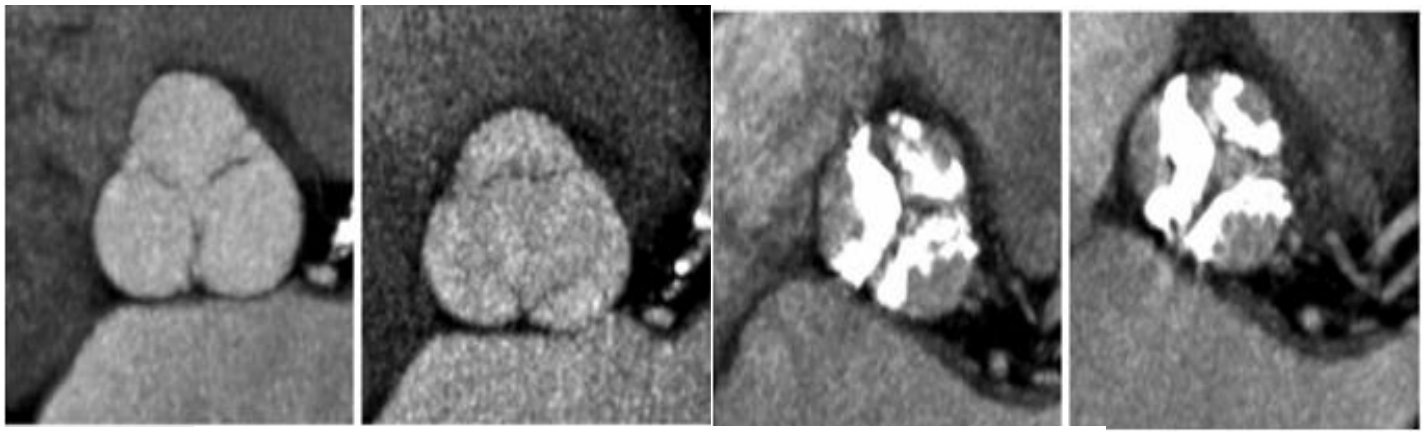
Assessment of perfusion and viability by multi-detector row computed tomography. First-pass and delayed enhanced multi-detector row computed tomography myocardial imaging in a porcine model of subacute myocardial infarction. (*A*) demonstrates an 'early defect' in the anterior wall (arrows) during first-pass of the contrast bolus; (*B*) demonstrates a hyper-enhanced, 'late defect' in the anterior myocardial wall (arrows) imaged 10 min following contrast infusion.

C. *Valvular disease*

- MDCT is helpful for the detection of Valvular abnormalities such as thickening of the mitral valve leaflets, presence of mitral annulus calcification, and calcification of the valvular leaflets.
- MDCT permits reliable assessment of aortic valve stenosis and regurgitation

CT imaging may develop into an alternative imaging tool in

- ✓ Patients who require exact assessment of the opening or regurgitant orifice of the aortic or mitral valve and
- ✓ Whom other more commonly used methods, such as echocardiography and magnetic resonance imaging, fail to provide all relevant information



Assessment of valve disease by multi-detector row computed tomography. Aortic valve morphology assessed by computed tomography. Upper row: normal aortic valve (left: systolic phase of the heart cycle; right: diastolic phase); lower row: severely calcified aortic valve with aortic stenosis (left: systolic phase of the heart cycle; right: diastolic phase).

5. Triphasic CT

Indication: *Scanning liver into 3 phases to differentiate between HFLs*:

- Detected **HFL** BY US(difficult to differentiate cirrhotic nodules from focal lesion by US)
- Suspected HFL in cirrhotic patient
- Metastatic work-up
- Follow-up after chemoembolization of liver malignancy (primary or metastatic)
- Patients who have had a liver transplant

Requirement:

- Wide **bore cannula** is mandatory for fast contrast injection(pump injection is better used at rate 5ml/sec)
- Precise **helical** CT machines (dynamic with no delay).....differentiate HFL by blood supply, pattern of enhancement.

Contrast:

- **Oral water** The use of oral contrast medium may change with multidetector CT because of the increased use of non-axial reconstructions and the potential for high-attenuation oral contrast medium to degrade the reconstructions. *In these situations, water is recommended as an oral contrast agent*

- **Optiray 350 IV contrast**(100ml contrast volume)
  - ✓ Scans should be done in single breath for each phase
  - ✓ Injection should be performed to administer entire contrast load in approximately 25-30 sec.Therefore, rate for 125 mL will be at 4mL/sec, and rate for 150 mL will be 5mL/sec
  - ✓ A higher mA (approx. 350 depending on size of patient) should be used to better resolution.

" **NB: Rapid or low-volume (shorter-duration) injections produce earlier peak enhancement, whereas slow or high-volume (longer-duration) injections result in later peak enhancement**".

Technique: Use MDCT helical scanner

CT phases of enhancement are acquired:

1. *Non-contrast/unenhanced acquisition*
   - Not technically a phase of enhancement that serves as baseline for measuring enhancement
   - Lesions have variable attenuation relative to liver
     - ✓ All solid organs and vessels appear gray
     - ✓ Areas of calcification will have very high attenuation
2. *Early arterial/hepatic arterial phase*
3. *Late arterial/portal inflow phase*
4. *Hepatic venous/portal venous/parenchymal phase*
5. *Delayed/excretory/equilibrium phase*

	Early arterial/ hepatic arterial phase	Late arterial/ portal inflow phase	Hepatic venous/ portal venous/ parenchymal phase	Delayed/ excretory/ equilibrium phase
Timing	**10-20 sec after IV contrast** "The 20-second interscan delay between the end of the arterial phase and the onset of the portal phase acquisition was needed to give the patient a chance to rebreathe and to reposition the scan plane cephalad to the liver "	**25-35 sec after IV contrast**	**50-75 secs after IV contrast**	**2-3 min after IV contrast**
As. vs. liver	▪ Arteries enhance ▪ Portal and hepatic veins not enhanced	▪ Arteries enhance ▪ Portal veins begin to enhance ▪ Hepatic veins not enhanced	▪ Liver parenchyma enhances ▪ Portal veins begin to enhance. ▪ Hepatic veins enhance	Liver parenchyma and vessels have washout of enhancement and appear gray again
Spleen, kidneys		▪ Spleen has heterogeneous enhancement ▪ Kidneys usually in corticomedullary phase of enhancement	▪ Spleen has homogenous enhancement ▪ Kidneys may be in corticomedullary or nephrogenic phase of enhancement	Collecting systems opacified with excreted contrast
Clinical implication "Lesion Detection"	Useful for CTA delineation of arterial anatomy for presurgical planning Hyper vascular lesions may enhance (can increase lesion detection by 8-13%)	Hyper vascular lesions seen to best effect "hepatocellular carcinoma, islet cell tumor, carcinoid, sarcoma"	▪ Hypo vascular lesions seen to best effect ▪ Hyper vascular lesions may washout enhancement	May be useful to evaluate some hepatic lesions: Hemangioma, FNH, Cholangiocarcinoma
Tips& tricks	Improved by ↑concentration of injection rate of contrast "iodine flux is the most important factor"	Improved by ↑concentration or injection ate of contrast "iodine flux is the most important factor"	Improved by ↑concentration or volume of contrast Total grams of iodine delivered is the most important factor General target range: 37-48 grams of iodine	

Parameters:

- Acquire all images from lung bases to iliac crests (delayed down to SP)with 1.5mm collimation
- Reconstruct 5mm axial slices for all phases
- Scan time : **25-30 sec** single breath hold
- Acquired time for each scan about 10 sec
- Filming: every phase on 20 image film (A,V).....**we put liver only** (rest of abdomen on delayed film)

Application:

Comparison of the sections at the same anatomic level in the three different phases of contrast enhancement

Most **hepatic tumors take supply from hepatic A** ,thus enhance in arterial phase, and of similar density to liver parenchyma in PV phase:

- Hemangioma… Globular or nodular intense peripheral enhancement during dynamic bolus phase with progressive Centripetal Fill-in occurs within minutes after administration of contrast (longer for giant hemangioma)
- HCC..... early arterial enhancement with rapid washout
- FNH (focal nodular hyperplasia).....delayed enhancement of central scar
- Cholangiocarcinoma……delayed enhancement fibrous stroma)

Arterial **PV** **Delayed**

6. CT PORTOGRAPHY/HEPATIC ANGIOGRAPHY

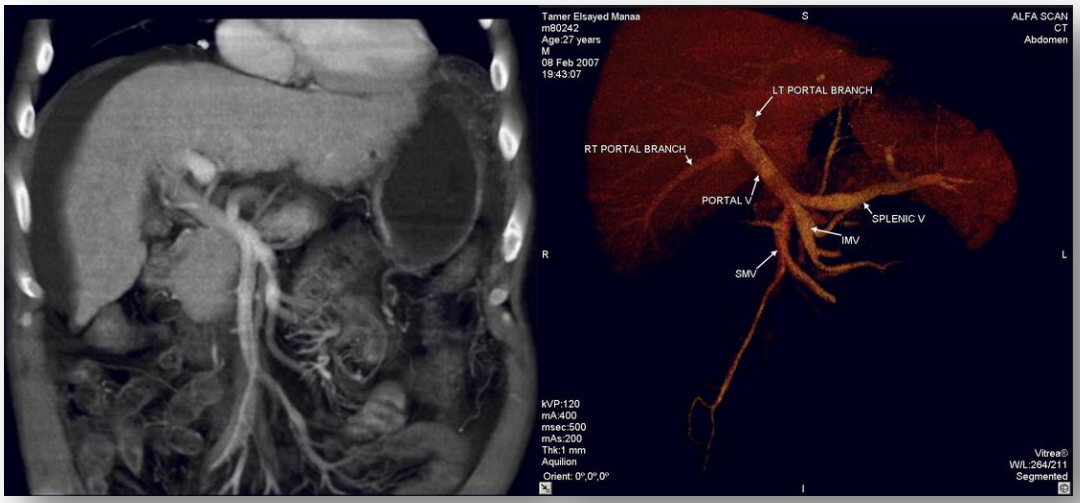
CT portography/CT hepatic angiography provides:

- The sensitivity of CT portography in detecting focal hepatic lesions and
- The specificity of CT hepatic angiography in distinguishing perfusion defects from true lesions

The study is performed via a single arterial puncture using a sheath, injectable guide wire in the hepatic artery and small caliber catheter in the superior mesenteric artery

- **"First pass"** The initial injection is into the SMA, The liver is scanned caudad to cephalad 20 sec scan delay.
- **"Second pass"** The second injection is into the hepatic artery, The liver is scanned cephalad to caudad, 10 sec delay.

Injection rate: 3 cc/sec for 40 seconds per injection



7. RENAL STONE protocol

The bladder should not be empty; preferably it should be full in order to better assess the ureterovesical junction.

- ## *Contrast:*

No oral, no IV initially

If IV contrast is needed, timing is based on why IV contrast is being given:

- ✓ 3-4 ml/sec for 125 ml (Optiray 320)
- ✓ 80 sec delay, scan 5 mm top of liver to SP for incidental abdominal pathology
- ✓ 6 min scan delay or longer, 5 mm top of kidneys through SP for delineation of ureters

- ## *Scan method:*

  - 5mm, single breath top of kidney to bottom of bladder, reconstruct at 2.5 mm intervals
  - When stone is detected in ureterovesical junction Vs bladder, acquire axial images through the bladder in prone position

- ## *NB:*

  - Most ureteral stones are at UVJ Look for ureteral stone and secondary signs (i.e. hydronephrosis, periureteral or perinephric stranding, enlarged kidney, delayed nephrogram or pyelogram)
  - Look for other pathology: Pancreas, appendix, diverticulitis, TOA, etc.
  - AIDS patients on protease inhibitors (i.e. Indinovir) may have non-opaque stones.
  - If questions of small stones Vs phlebolith, you must do retrospective reconstructions at 2.5 mm through area of concern

- ## *Dual source CT scanners basic principle:*

  I. Two x-ray tubes can be set at different energies (kVp) and dual energy scans can be acquired concurrently.

  II. The spectra of X-ray attenuation of different materials depend on their material composition. The attenuation of soft tissues does not vary much within the energy range used in CT, but materials containing substances with high atomic weight, such as calcium, vary considerably.

  III. Uric acid and non-uric acid stones behave differently with respect to their attenuation values when scanned with CT at different energies.

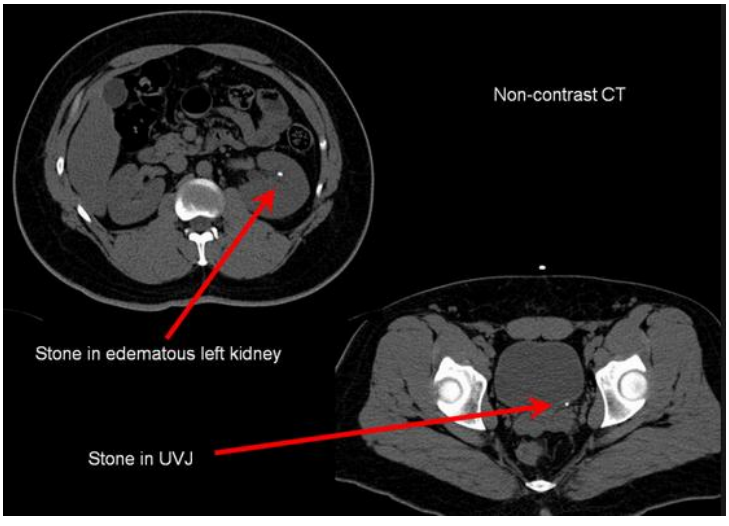
  IV. Software is available with dual source CT scanners that takes advantage of these differences and uses a decomposition algorithm to differentiate between uric acid stones, non-uric acid stones, and soft tissue.

  V. The resultant images are color coded to show uric acid stones as **red** (Figure 1) while non-uric acid stones, bone, and other calcified deposits are depicted in **blue**

  VI. Dual Energy CT Renal Stone Protocol

  In order to minimize radiation exposure,

  - The patient is first scanned with a standard low-dose renal stone CT, using a tube potential of 120 kVp and very low tube current.
  - Scanning range is customized to cover the region of interest.
  - A radiologist reads the CT while the patient remains on the scanner table and if a stone is detected, a second dual energy scan (using 80 kVp and 140 kVp) is performed focusing on the region of the stone only.



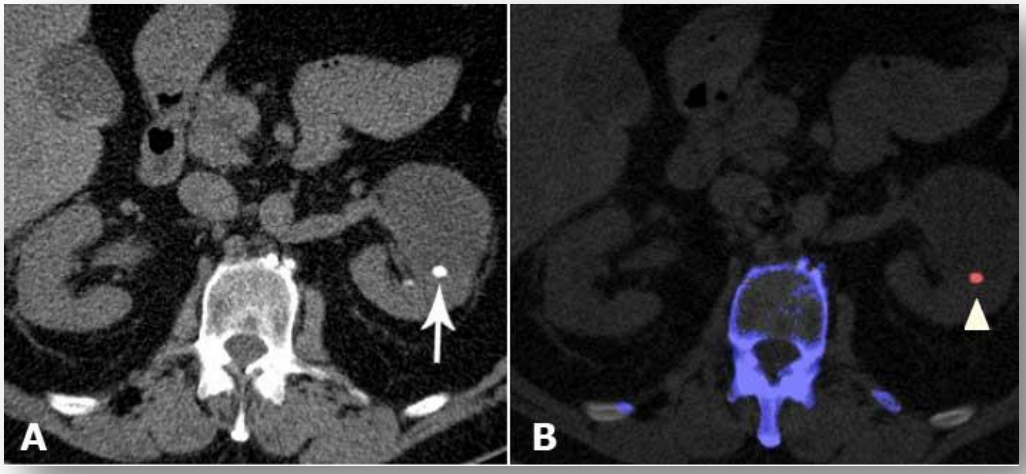


Figure 1. (A) Axial unenhanced abdominal CT scan in a 43 yr-old-man shows a calculus in the left mid pole (arrow). **(B)**Corresponding color-coded dual energy post processed image shows the calculus coded as red (arrowhead) indicating a uric acid stone

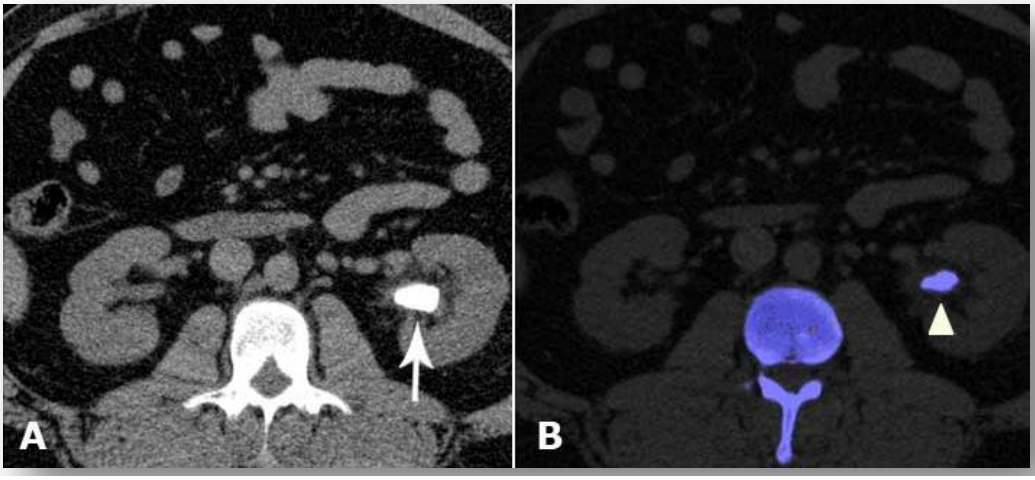


Figure 2. (A) Axial unenhanced abdominal CT scan in a 36 yr-old-man shows a large calculus in the left renal pelvis (arrow). **(B)** Corresponding color-coded dual energy image after post-processing shows the calculus coded as blue (arrowhead) indicating a non-uric acid stone.

8. Renal protocol……RENAL MASS

Contrast:

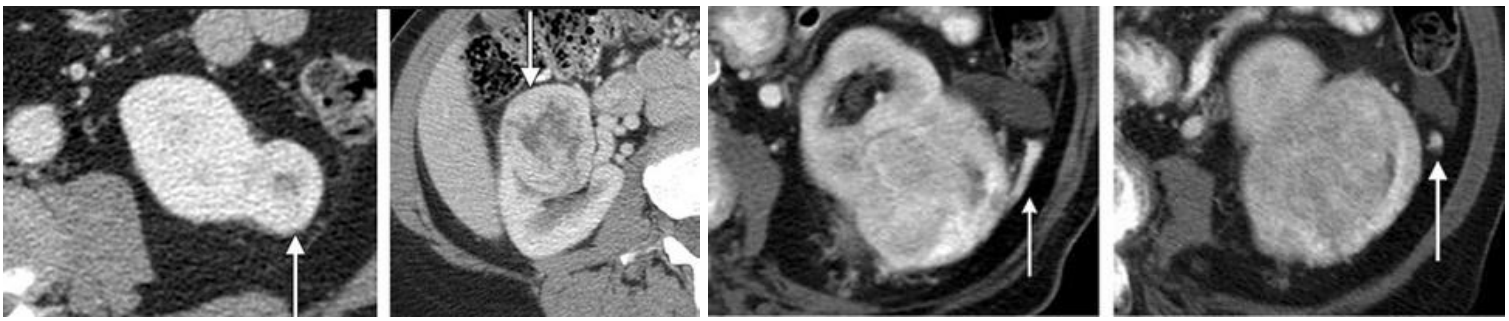
- ✓ Oral contrast
- ✓ 125 mL Optiray 320 4-5mL/second

Scan Method:

1. **Non-contrast** – 5mm RS=0.8 (same for remainder) top to bottom of kidneys using same MA as post IV scans
2. **Corticomedullary Phase** – 5mm 30 sec delay with 2.5 mm recons- Top of liver to bottom of kidneys
3. **Nephrographic Phase** – 5mm 80 sec delay with 2.5 mm recons- Top of liver to SP
4. **Delayed Phase** – 5mm 3 minute delay with 2.5 mm recons– Top of liver to bottom of kidneys

NB:

Low attenuation masses in the medulla may be missed if only corticomedullary phase scanning is performed



9. CTU

Performed for hematuria work-up or known/suspected urothelial malignancy

Preparation:

Patient should have moderate distension of the bladder (don't let go to the bathroom before scanning) or the Foley catheter must be clamped at the beginning of the exam.

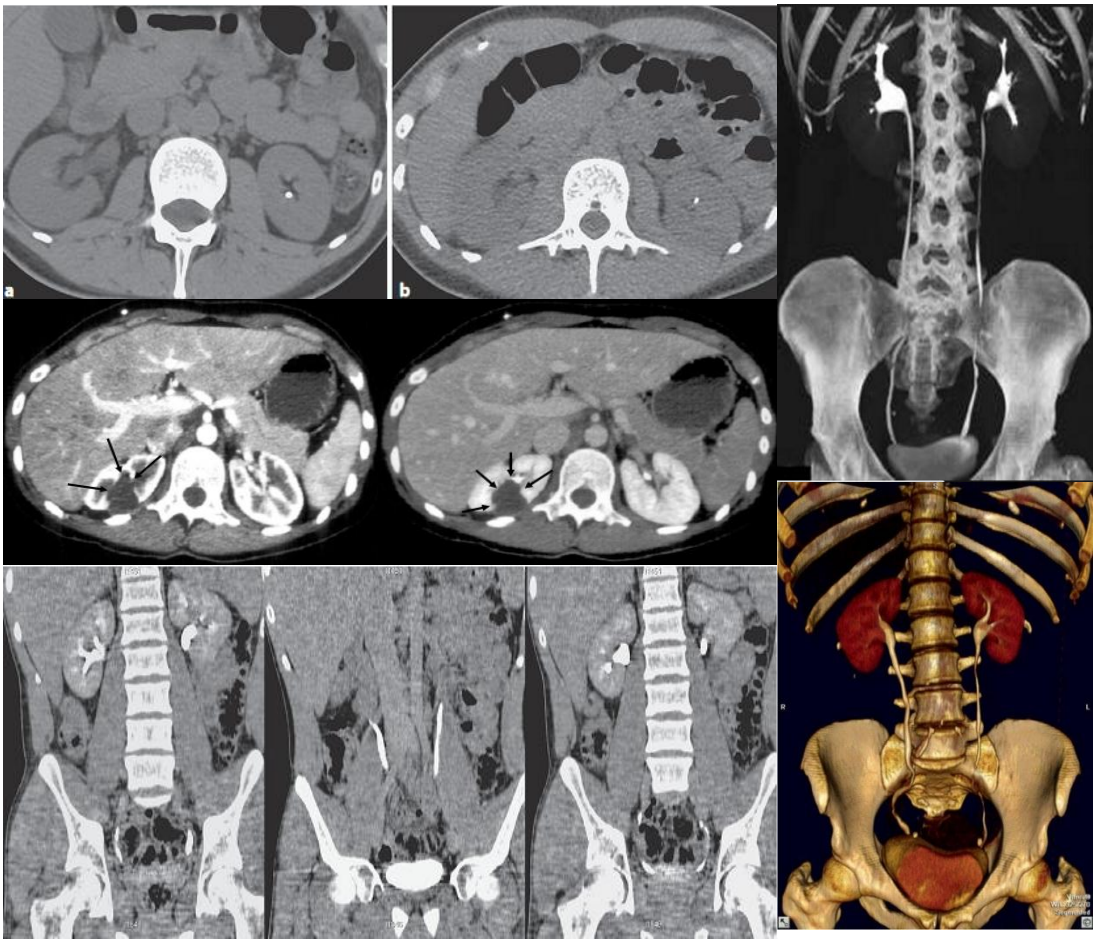
Contrast:

- No oral, patient should drink 32 oz of water upon arrival to department; patient should be well hydrated and encouraged to drink
- 125 mL Optiray 320 at 3-4 mL/sec with 250 cc of normal saline via IV immediately following

Scan method:

Combines unenhanced, nephrogenic phase and excretory phase

1. **Non-contrast**…..5 mm, recon 2.5mm from top of kidneys to iliac crest… **detects renal calculi**
2. **Nephrogenic phase** …delay 80 sec, 5mm with 2.5mm recon from dome of liver to SP **detect renal parenchymal abnormalities (esp. masses).**
3. **Excretory phase**…Wait 8 minutes, perform a AP KUB (scannogram) **to evaluate ureter opacification, urothelial disease**
    - If most of the ureters tract are visualized, scan entire abdomen (2.5 mm with 1.25mm recon), usually a 15 minute scan is best to opacify distal ureters
    - If KUB does not show opacification of ureters, obtain another KUB using 1 minute intervals until adequate opacification is achieved
    - If a portion of ureter is not opacified on delayed scan, rescan the unopacified segment after standing the patient and placing in the prone position.



10. CT CYSTOGRAPHY

If bladder injury is suspected because of multiple pelvic fractures

Scan method

Following the routine abdominal CT, We have to actively distend the bladder in order to exclude bladder injury

"Passive filling of the bladder via the IV injection is not sufficient to exclude rupture"

- Possible urethral injury should be excluded by trauma or emergency team
- Inject 200-300 cc of dilute contrast in bladder via Foley catheter by gravity

"Dilute contrast is a 2-3% solution of iodine (100 cc of 320 Optiray contrast in a 1 liter saline bag) "

- Rescan lower abdomen and pelvis
  - ✓ Check for intra-peritoneal extravasation along gutters and between bowel loops
  - ✓ Check for extra-peritoneal extravasation anterior to the bladder and along the anterior abdominal wall and scrotum
- Post-void images are not necessary

11. Adrenal protocol

Use this protocol for evaluation of patient with a known adrenal lesion that has been previously incompletely characterized or in patients with biochemical evidence suggestive of adrenal pathology

Contrast

- No oral
- 125 mL Optiray 320 at 3-4 mL/sec

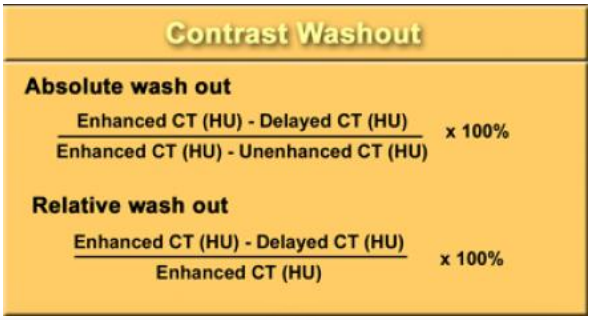
scan method

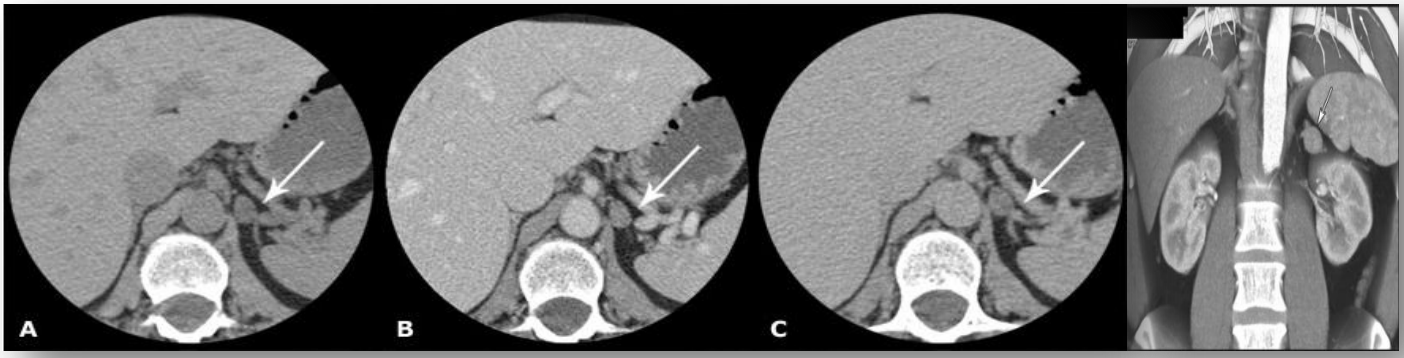
1. **Unenhanced CT……**5 mm, single breath from liver dome to bottom of kidneys, reconstruct at 2.5 mm intervals
2. **Enhanced phase (60 sec)**…… 5mm. Scan from the liver dome to the SP in this acquisition if evaluation of the pelvis is desired, otherwise only the abdomen (top of liver to bottom of kidneys) needs to be scanned – reconstruct at 2 5 mm intervals
3. **Delayed phase (15 min)**…… 5 mm. (top of liver to bottom of kidneys) – reconstruct at 2.5 mm intervals

NB:

If the noncontrast images demonstrate a homogeneous lesion that is less than 10 HU, the lesion is highly likely to be an adrenal adenoma and no further imaging is necessary

Therefore, the radiologist should check the noncontrast images prior to proceeding with the remainder of the study unless evaluation of the entire abdomen and pelvis was requested for other reasons.


Contrast Washout
Absolute wash out
Enhanced CT (HU) - Delayed CT (HU)
Enhanced CT (HU) - Unenhanced CT (HU)
x 100%
Relative wash out
Enhanced CT (HU) - Delayed CT (HU)
Enhanced CT (HU)
x 100%



CT images of a 1.3 cm left adrenal nodule (arrows) in a 42 year old woman representing a typical adrenal adenoma with (A) unenhanced attenuation of 4HU, (B) IV contrast enhanced (performed for other indications) attenuation of 64 HU and (C) 10 minute delayed attenuation of 30 HU. The adenoma has a relative percentage washout of 53% and an absolute percentage washout of 57%

13. CT Enterography

This protocol is for evaluation of the small bowel

Indication

- Crohn disease,
- Intermittent small bowel obstruction (such as adhesions, etc. in an outpatient setting),
- Evaluation for small bowel tumors, and
- obscure gastrointestinal bleeding (continued GI bleeding despite negative upper and lower endoscopy)

"You must specify in the protocol whether you want an arterial and portal venous phase study (CT Enterography for GI Bleed) or portal venous phase only (CT Enterography for Bowel Disease)"

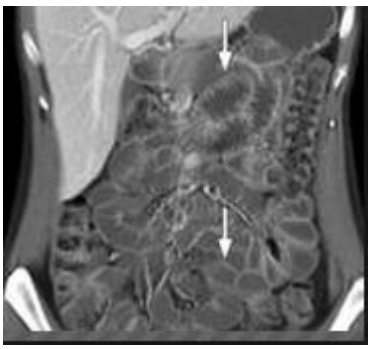
Contrast

1. **Volumen, low attenuation oral contrast per protocol** …….**NB: Various types of intraluminal CM are used to provide +ve/-ve Contrast between bowel lumen, surrounding structures**
   - ✓ **Positive contrast agents with high attenuation**
     - **Advantage**
       1. Differentiate bowel loops from
          - Enlarged LNs
          - Extramural fluid collection as abscess
       2. Detect SI obstruction or fistulas
     - **Disadvantage:** mural enhancement after IV injection may obscure subtle Crohns lesion
   - ✓ **Negative CM**… Facilitate depiction of wall of normal, diseased bowel segments particularly after CM(The enhancing wall bowel is well depicted adjacent to the low-attenuation fluid in the lumen)
     - Enhancement is usually greater on mucosal aspect of bowel wall w' shouldn't be mistaken for a disease process.
     - If wall isn't Thickened ,no perienteric inflammation present ……will differentiate normal enhancement from a disease process
2. **125 mL Optiray 320 at 3-4 mL/sec**

Scan method

- For Crohn disease or other diffuse bowel pathology; Portal venous phase study only is sufficient
- For occult GI bleeding and search for GI malignancy: arterial, portal venous and delayed scans are usually needed

Before giving IV contrast perform a low mA single slice through mid-abdomen or topogram and check if there is adequate bowel distention (Make sure most of Volumen is not in stomach)



1. **Arterial phase study** – 5mm with 2.5 mm reconstructions with a smart prep (HU=100), top of liver to SP
2. **Portal venous phase study(80sec)** – 5mm at 80 sec delay Scan from the liver dome to the SP – reconstruct at 2.5 mm intervals
3. **Delayed Phase (3min)**– 5 mm, top of liver to bottom of kidneys

(a) (b)

CT enteroclysis coronal image (a) shows better distension of the jejunal loops (J) than CT enterography with polyethylene glycol (PEG–CT) coronal image (b)

14. CT Enteroclysis

Methods

1. **1ry method:** Neutral enteral CM (like water attenuation) with IV CM
   Advantage: allow MPR without artifacts, show mucosal enhancement
2. **Positive enteral CM** without IV CM
3. **Negative enteral CM**
   - ✓ Water (preferred)
   - ✓ Methylcellulose

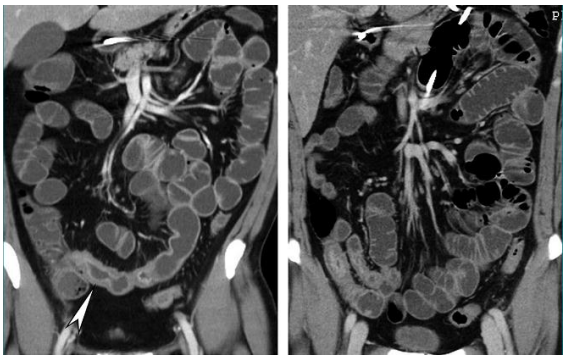
1. 1ry method

Fluoroscopic phase:

- 13-F Enteroclysis catheter is used, Balloon is positioned to the left of the spine. 60ml of air is injected through the catheter under fluoroscopy following balloon inflation
- 0.3 ml of glucagon is administered IV
- 1.5L of water is infused initially at 130ml/min Rate is adjusted… Transfer to CT table (infusion stopped during transfer)

CT phase:

- 0.3 ml of glucagon is administered IV If glucagon is contraindicated, barium sulfate or methylcellulose is used
- 1.5L of water is infused at 100-150 ml/min
- IV contrast material is administered at 4ml/sec, Total 150ml……CT is performed at 50-sec delay to obtain optimal bowel mucosal enhancement
- Balloon is deflated and refluxed water in stomach is aspirated



2. Positive enteral CM

Fluoroscopic phase:

- 13-or14-F catheter is used balloon catheter tip is positioned in descending duodenum 60ml of air is injected through the catheter under fluoroscopy following balloon inflation
- 12%water-soluble contrast material:2L plus infusion rate at 55-150ml/min(adjusted for optimal enteral volume challenge)
- Limited fluoroscopy and radiography till contrast material is in cecum

CT phase:

- 500-1000ml of water soluble contrast material is infused on CT table before and during scanning
- Infusion rate increased by 10ml/min from the rate of infusion during fluoroscopy
- Enteroclysis catheter withdrawn to stomach and contrast material is suctioned.